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ANNUAL REPORT
RANGE REVEGETATION INVESTIGATIONS

FORAGE & RANGE BRANCH
CROPS RESEARCH DIVISION
AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

INTERMOUNTAIN FOREST
AND RANGE EXPERIMENT STATION
and
UTAH AGRICULTURAL EXPERIMENT STATION

by

A. T. BLEAK, RANGE CONSERVATIONIST
EPHRAIM, UTAH

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Bureau of Land Management

Forest Service, Region 4

Intermountain Forest and Range Experiment Station

Soil Conservation Service

Utah State University

Appreciation is expressed to all personnel who assisted in laboratory or field work, reviewed study plans or manuscripts, and for their many helpful suggestions. Special thanks are due the Intermountain Forest and Range Experiment Station and Forest Service, Region 4, for providing office and storage space and other services.

NOT FOR PUBLICATION - This is a progress report of cooperative investigations containing data, the interpretation of which may be modified with additional experimentation. Publication, display or distribution of any data or any statements herein is prohibited without prior written approval of the Crops Research Division, ARS, USDA, and the cooperating agency or agencies concerned.

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I. INTRODUCTION — CRc6: PASTURE AND RANGE INVESTIGATIONS UNDER ARID, SEMI-ARID, AND SUB-HUMID CONDITIONS INCLUDING SILAGE AND HAY PRODUCTION.

The following report covers the artificial revegetation investigations conducted in central Utah during the period April 1, 1957 to March 31, 1958. This is the second report that has been submitted since the work was reactivated in the summer of 1956.

This position was without assigned personnel from March to July 1, 1956. Work conducted since that date includes completing all field work on major studies in Nevada, reactivation of established work in Utah, and establishment of new studies to determine some of the factors influencing success or failure on harsh sites, especially at high elevations.

New work initiated in central Utah in the fall of 1956 includes laboratory studies on seed germination; behavior of seeds and seedlings under a snow cover during the winter and spring months; damage to seeds or seedlings from fall plantings; and a study to determine if flooding occurred during rapid snowmelt in the spring. These studies have been continued and similar studies based on this work have been initiated to further explore the factors influencing the success or failure on range seedings.

Foreign Visitors and Technical Assistance

Approximately 8 hours were spent with Mohsen Kheradpir from Iran. In addition, 78 hours were spent giving technical assistance and reviewing findings with extension workers, action agencies and private groups.

II. CRc6-2: EVALUATION OF GRASSES AND LEGUMES ALONE AND IN COMBINATION FOR ADAPTATION TO RANGE CONDITIONS

Suitable species are needed to increase forage production, to maintain soil stability and prevent destructive floods. Species should be used which are adapted to the environment. Species may be well adapted to a particular climate or soil but still fail because of some other environmental factors. This has led to an effort to distinguish between those inherent climatic and edaphic factors which must be met by species selection as opposed to factors such as grazing use, insects, rodents, and disease.

II-A. DESERT RANGE LANDS OF THE INTERMOUNTAIN REGION

Desert range lands of the Intermountain Region have been seriously depleted. At present there is urgent need to rehabilitate vast areas of these ranges to stop further deterioration by wind and water erosion, to stop deposition of sediment in lakes, reservoirs, and river basins like the Colorado and Virgin, to control noxious weeds, and to increase forage production especially on winter ranges for livestock and game.

Because of climatic conditions, returns from the land are low in the desert types as compared to other range types. From the evidence we have to date, vast areas can and should be rehabilitated through management. However, artificial revegetation is needed and justified on critical areas that need rapid rehabilitation and on better lands where the returns will offset the cost of operation.

Desert range lands of the Intermountain Region can not be considered as a single homogenous type similar to the big sagebrush or pinyon-juniper types. These desert lands include two major types even when considered from a very broad point of view.

The southern desert shrub type is characterized by high summer maximum temperatures, often above 100° F., for 5 or 6 months of the year, mild winters, and a drought period in both spring and fall. In the northern shrub type maximum temperatures above 100° F. are rare and there is usually a cold rest period during the winter and a drought rest period in midsummer.

1. Southern Desert Shrub Type

The southern desert shrub type begins near the Hurricane fault in southern Utah and runs westward into Nevada and crosses into California, south of Goldfield, Nevada. Most of the precipitation in this type is of winter origin with infrequent cyclonic summer storms. This area coincides with the red desert soils. To better delineate the problems in range management and artificial revegetation, the southern desert shrub type has been broken down in two vegetative types.

a. Blackbrush (Coleogyne ramosissima), type or association lies in a broad overlapping belt between the northern and true southern desert shrub type. It is accompanied by both northern and southern desert plants.

Plants commonly found associated with blackbrush are spiny hopsage (Gravia spinosa), Joshuatree (Yucca brevifolia), bur-sage (Franseria dumbosa), Indian ricegrass, scattered areas of galleta grass annual brome and other annuals. As a rule this association occupies light pervious land. Soils are usually sandy, rocky, or gravelly with a definite erosion pavement in the open spaces between the shrubs and with an accumulation of fine soils under the shrubs. These lands are free from harmful amounts of salts or alkali. Precipitation is between 5 to 10 inches annually with high summer temperatures and high evaporation.

In general the carrying capacity of this type is low. However the scanty leafage of blackbrush is persistant and available throughout the year. It is reported to provide fair forage for cattle, sheep, goats, and game during the winter. Blackbrush furnishes little forage in the spring or fall.

Many of the blackbrush stands are closed to the interstitial production of annuals. During the past 15 years, several large areas of blackbrush have burned. Removal of blackbrush, cactus and other shrubs by burning results in increased forage production, especially the annual bromes, alfileria and other broad leafed herbs. It has also been noted that (Gutierrezia) increases with each additional fire, and will undoubtedly be a problem in attempts to artificially seed these areas.

b. Creosote-bush, (Larrea tridentata) and bur-sage (Franseria dumosa) dominate the true southern shrub type located in southern Utah and southern Nevada usually below 3500 feet elevation. Soils are usually pervious and covered with a prominent desert pavement. Annual precipitation probably ranges from 3 to 8 inches per year. The dominant shrubs are usually widely spaced. When winter precipitation has been adequate, carpets of flowering annuals cover the ground between and under the shrubs in the early spring months. By May these annuals have disappeared. If an area in this zone receives precipitation from one of the late cyclonic summer storms, there usually will appear another but different aggregation of blooming annuals. Due to the irregularity of these local storms, a given area may not be subjected to such a storm more than once in several years.

Very few live streams cross this type and those that do originate in other types at higher elevations. There is little or no surplus water in any season and the desert pavement does a fair job of controlling normal wind and water erosion in this type. However, local floods from torrential cyclonic storms are not uncommon and active sand dunes are common in some areas.

This type is of restricted importance as a forage type due to limited and uncertain production of forage. Grazing of domestic stock is further curtailed by lack of drinking water. A few areas need revegetating to control siltation of streams and reservoirs and to control wind and water erosion. The limited and irregular precipitation plus high temperatures and high evaporation increase the problem and difficulties of successful artificial revegetation.

2. Northern Desert Shrub Type

The northern desert shrub type occurs mainly toward the southern and southwestern parts of the Intermountain Region. Big sagebrush is not considered to be a major species in the northern desert shrub type in this report. The largest continuous area extends from the Carson Desert of west central Nevada south and east to the dry mountain region of Death Valley and southern Nevada. This type forms a distinct zone between the sagebrush zone to the north and the southern desert zone to the south. A second large area lies in the arid portions of western Utah. A third area is located in the Green and Colorado River drainages of eastern Utah and western Colorado. Isolated islands of this type extend northward into eastern Oregon, southern Idaho, and southwestern Wyoming.

In general it can be said that the climate of this zone is distinctly drier than the sagebrush zone. The mean annual precipitation for six desert shrub stations in western Utah averaged 7.95 inches, while that for four sagebrush stations averaged 14.84 inches or again almost

twice as much as in the desert shrub type. At 11 stations in western Nevada and eastern California, the northern desert shrub type mean annual precipitation ranged from 3.08 inches to 5.68 inches with an average of 4.51 inches for the zone. This is about one-half the average mean annual precipitation of 8.79 inches for 6 stations in the sagebrush zone in northern and western Nevada.

Mean January temperatures in the northern desert shrub appear to be higher than in the sagebrush zone. The summer temperatures of the northern desert shrub in western Nevada are distinctly higher, about 5° F., than those in the sagebrush zone. The higher summer temperatures in the desert shrub zone are undoubtedly reflected in higher evaporation, resulting when coupled with lower precipitation in greater aridity.

The northern desert shrub type can be conveniently broken down into several distinct communities or associations. These are permanent communities, to some extent determined by soil conditions within the limits set by climate. The most important or largest communities are listed below in the order in which they frequently occur in going from the big sagebrush type toward the heavier moister soils surrounding a lake or marsh on the valley floor.

a. Black sagebrush (Artemisia nova) is one of the most desirable native forage plants on winter sheep ranges. This plant is apparently a transition form between the desert shrub type and big sagebrush. In this discussion, areas of blackbrush bordering on the desert shrub type will be considered a part of the desert shrub type, since problems encountered in rehabilitation of this type are similar to those of the desert shrub type.

Black sagebrush occupies land where the available soil moisture is too low for big sagebrush. The soil may be shallow, too well drained, or run-off may be high, due to heavy impervious soil. Most of the black sagebrush ranges have been seriously depleted and many have been invaded by little rabbitbrush, shadscale, and other plants common in the desert shrub type.

b. Galleta grass (Hilaria jamesi) occupies the higher land and sometimes borders or mixes with sagebrush areas or adjoins them. Soil texture in galleta associations is not distinct from that found in the sagebrush type, particularly where growth is dwarfed. Good growth of galleta grass requires less moisture in spring than does sagebrush. Also it is better adapted than the shrubby types of vegetation to make use of slight increases of moisture in the topsoil due to summer rain. It is quite likely that this grass once occupied portions of the shallow soils now covered with dwarfed sagebrush or little rabbitbrush.

Galleta grass indicates a well drained soil that is nonsaline, of light texture and permeable. It also indicates that there is available soil moisture in at least the first two feet in the spring and little or no available soil moisture in the fall except in the surface soil following a rain. This plant is superior to some of the shrubs as winterfat and shadscale in controlling wind and water erosion. It not only keeps soils from blowing but builds up the soil by catching and holding wind blown particles. It is a short grass of medium to low palatability.

c. Winterfat (Eurotia lanata) occurs as a scattered plant from the grass lands of Montana to the desert lands of the southwest. On desert range lands in the Intermountain Region it is often found in nearly pure stands and also mixed with shadscale, greasewood and galleta grass. Sagebrush and little

rabbitbrush are not common in winterfat areas and are usually confined to drainages and lighter soils where soil moisture conditions are more favorable (fig. 1). The winterfat association usually indicates a soil of heavier texture and less favorable soil moisture than is found under galleta grass, little rabbitbrush or sagebrush. This plant does well where there is a good supply of soil moisture only in the upper 2 feet in the spring. Soils are usually dry in the fall and winterfat apparently benefits but little from summer storms.

Winterfat does not endure high concentration of salt. The upper 2 feet of soil normally have a low salt content, but the deeper soils may have a high salt content. Winterfat lands may be classed as near the border line between saline and nonsaline lands.

d. Shadscale (Atriplex confertifolia) dominates more area in the northern desert shrub type than any other association. On typical shadscale areas the first foot and usually the second foot have a low salt content. In the third and fourth foot the salt content may be high, occasionally as much as 2.5 percent of salt. However, if the salt content is high in the first foot the shadscale plants are sickly and the stand is thin. Further, shadscale is not a reliable indicator of saline subsoils. This is particularly true on the better drained soil where drought conditions are severe. The presence of salts in the deeper layers of the heavier soils may indicate the zone of maximum percolation of soil moisture during the winter.

Shadscale is usually indicative of soil which is very dry in summer. In the spring there is usually a good supply of available moisture in the first and second foot but at the fourth foot, available moisture is usually lacking. In the fall there is little or no available water below the first

Figure 1 .—The big sagebrush fingering out into this nearly pure stand of Eurotia lanata is located in or on the banks of a small channel that heads in the foothills west of this photo. Note that the big sagebrush stops where the channel terminates (B57-85).

Where? + Date?

foot and only then after heavy rains. Shantz and Piemiesel have shown that shadscale can endure more severe drought than either sagebrush or greasewood. This is supported by the occurrence within the shadscale areas of sagebrush or greasewood wherever soil moisture conditions are more favorable.

Shadscale areas are found where available moisture is too low or the soil is too saline for sagebrush. There appears to be no consistant textural difference between sagebrush and shadscale soils; either may possess subsoils which range from sand to clays. A desert pavement or erosion pavement is characteristic of much of the shadscale land.

Shadscale is usually sharply separated from sagebrush but may alternate with it where the soil is too well drained. Shadscale mixes readily with greasewood and both do well. In shadscale areas that border or mix with greasewood the soils are quite heavy. Where shadscale and greasewood are mixed, water in addition to direct precipitation is indicated. Because of a better supply of moisture shadscale usually makes a better growth under these conditions. It is likely that a water table high enough to benefit shadscale is too high for the best growth of greasewood. Shadscale suffers if the salt content in the surface foot of soil becomes too high and neither shadscale or greasewood grow well where the surface foot is constantly wet.

e. Greasewood (Sarcobatus vermiculatus) grows under a wide range of soil and soil moisture conditions. There are wide tracts of greasewood mixed with saltgrass, shadscale, rabbitbrush, winterfat, and even sagebrush. It is quite likely that this plant has invaded large areas formally occupied by other range types.

Typical areas of greasewood with reference to other associations lie below the shadscale belt and above the saltgrass and pickleweed where the soil surface is not so wet nor as saline as in the latter types. Stands of

uniform growth are usually found on a rather heavy soil where at least in spring the soil moisture supply is increased by a high water table or flooding. These plants also have a tap root which enables them to reach deep water tables. Plants most frequently occur where the depth to the water table is less than 15 feet though the upper limit may exceed 40 feet. This ability of greasewood to feed at great depths must be taken into account in considering soil moisture requirements.

Greasewood is not always an indicator of high salt content although it is usually found under conditions that also favor a concentration of salts. It is apparently indifferent to salts and if soil moisture conditions are favorable it can grow in very saline soils.

f. Saltgrass (Distichlis stricta). Where the influence of the water table reaches the surface, and this condition exists throughout the growing season, greasewood frequently gives way to saltgrass. A uniform saltgrass sod usually indicates a heavy type of soil, a high salt content and a good supply of soil moisture throughout the year. Saltgrass frequently occurs on level lands where at least in spring the water table is at or near the soil surface. It is able to tolerate a wide range of conditions and may be found on almost any soil except the very driest.

A high salt content is not necessary for good growth of this grass. While soils having as much as 2.5 percent of salts are suitable for saltgrass, it will grow well on nonsaline soil wetted by fresh water. Where the soils become drier this grass does not form a sod and plants are scattered. Its root system is shallow in water logged soils but may reach a depth of many feet where the water table is low. Saltgrass is not easily

injured by grazing and it readily reseeds itself. This grass now dominates large acreages formerly occupied by more desirable grasses and sedges that have been depleted.

g. Pickleweed (Allenrolfea occidentalis) is generally confined to flat, poorly drained areas in valley bottoms where it is closely associated with saltgrass and greasewood. This plant is found on heavy textured soil where there is usually an abundant supply of soil moisture throughout the year. The salt content in the upper 3 feet of soil is often as high as 2.5 percent and usually over 1 percent. This plant thrives where the soil surface stays wet all summer and has a high salt content. It furnishes little or no forage and has probably changed very little as a result of livestock use.

Seeding trials in the northern desert shrub type. In the pickleweed, saltgrass, and greasewood associations, physiological drought may be more of a problem than soil moisture. At this time, successful plantings can be made in the saltgrass and in some greasewood types. Experience has shown that these plants must be eradicated for successful artificial revegetation. Greasewood can be eliminated by wheatland plowing or similar methods. Saltgrass is more difficult to eradicate. The method which has given best results is to turn the sod completely under. This can best be done by moldboard plowing to a depth of 4 to 5 inches in the summer or fall when the soil surface is dry. Spring planting has been best on wet alkali lands and late fall or early spring planting is superior on dry alkali soils. Planting procedures which place the seed in a shallow furrow or depression have given better results than drilling directly into soil surface.

Species adapted to wet alkali areas with a high water table are tall wheatgrass, alta fescue, yellow sweet clover, fivehook bassia and Belvedere summercypress. Promising species on areas with a low water table which dries out in summer are tall wheatgrass, Russian wildrye and crested wheatgrass. On some of these areas, drought tolerance is more important than a tolerance to soil salts.

In the black sagebrush, galleta, winterfat, and shadscale associations, physical drought is the principal limiting factor. Plant growth is restricted by available moisture in the soil as a result of precipitation. Drought tolerance is generally more important than tolerance to high concentrations of soil salts. Work in these types is still in an exploratory stage and the prospects of large-scale seeding in the near future are not bright. Most of the trial plantings on desert ranges have resulted in failure. Many of these trials were planted by private individuals or by the Grazing Service and unfortunately there is little information of species planted or planting techniques. Even so it is quite apparent that limited moisture has been the principal cause of failure.

Successful plantings have been made on desert land at several locations in Utah. Some of these will be briefly discussed.

One of the most promising plantings was made by Mr. Victor Murray at Cisco, Utah in the spring of 1938. This planting is on clay soils derived from Mancos shale and supporting shadscale type of vegetation. Eighteen acres of crested wheatgrass were planted with a Planet Jr. in furrows previously made with a marker. In 1952 most of the plants appeared thrifty and there was a moderate number of young plants and seedlings.

A successful planting of crested wheatgrass was made in the winterfat type near the Desert Station west of Milford, Utah by drilling into a winterfat type (figs. 2 and 3. Part of this planting was made when the native vegetation had been eradicated and part was made by drilling directly into the winterfat. Total forage yields are similar in both plantings. However both crested wheatgrass and winterfat show the effects of competition where the two grow together.

Successful range plot plantings of crested wheatgrass and Russian wildrye have been made near Gunnison, Utah in the shadscale type in several different years. Many other species have been tried here with varying degrees of success.

Four plantings involving 82 species and strains were made within the Colorado River Drainage in the fall of 1950. While the success or failure of these plantings has not been fully determined results to date are not encouraging. Despite a dry spring in 1951, seedling stands of one lot of squirreltail, amur wheatgrass, crested wheatgrass, intermediate wheatgrass, pubescent wheatgrass and Russian wildrye produced fair to good stands on all sites. In the spring of 1952 there had been some mortality on most species, however, there had been some additional germination and emergence from the 1950 planting. At three of these sites, various methods of planting were tried in addition to the species plot tests. At Cisco, five species and two mixtures were planted by drilling directly into the prevailing cover and by broadcasting on plow furrows. The latter method was superior for all species and fair to good stands of crested wheatgrass were observed in 1952.

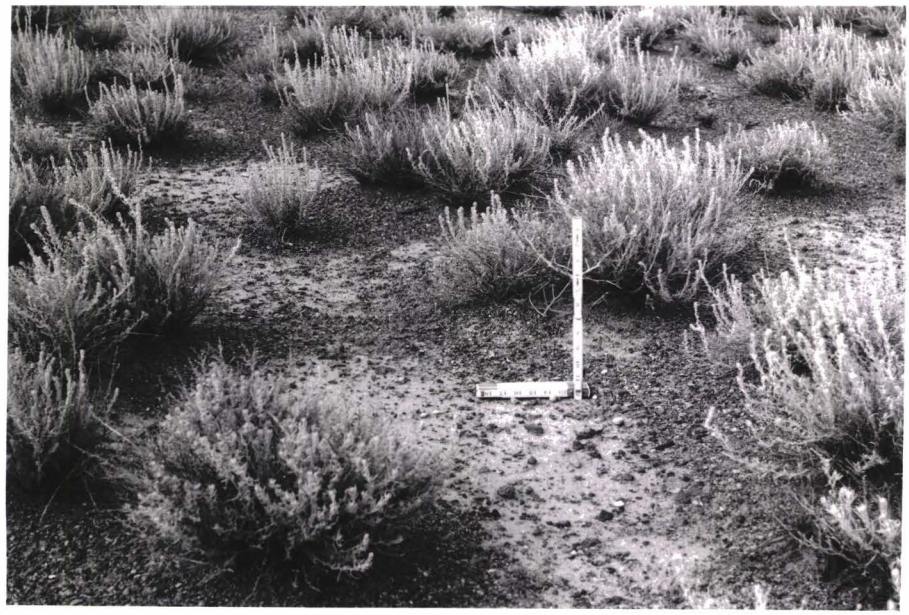


Figure 2 .—Note the size of the openings covered with erosion pavement between the Eurotia lanata plants in comparison to the basal area of these shrubs (B57-83).

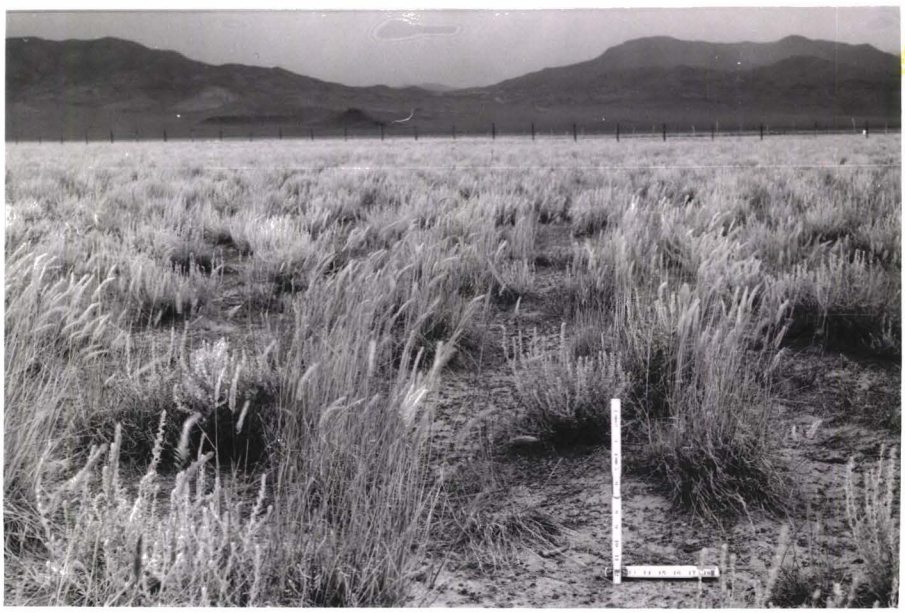


Figure 3 .—The crested wheatgrass in the stand of Eurotia lanata was planted in the fall of 1939 (B57-74).

On the Buckhorn Flats in central Utah the same species were drilled on land which had been previously treated with an eccentric disc. Poor to fair stands of crested wheatgrass and Indian ricegrass were observed in 1952. Near Castle Dale, Utah the same species were planted by direct drilling with no other soil preparation. This planting gave poor stands of all species except Indian ricegrass and these seedlings may have been from native seed sources.

In general, little success has been reported from plantings of native grasses, herbs, or shrubs. However, native shrubs have withstood the frequent droughts much better than most introduced grasses. It would appear that future work with perennials on these desert lands should emphasize shrub species, both native and introduced.

Revegetation in the desert shrub type will be expanded during the coming year. The old planting mentioned above and others should be thoroughly studied. Most of the action work will be with the germination and conditions necessary for germination of shrub species and strains of Hilaria jamesi and Sporobolus.

II-B. LEGUME-GRASS MIXTURE

This study was established to determine the best legumes for planting in grass-legume mixtures and determining the effects of the grass-legume mixture on yield of the grasses and legumes in range planting on mountain brush ranges.

Nine legumes including three separate strains of alfalfa were planted in mixture with each of four promising grass species in the fall of 1950. Species and strains used are listed below.

Grasses

Agropyron desertorum - Lot Ager 78, Commercial. Grown in Sanpete Valley, Utah in 1950.

Agropyron intermedium - Lot 42, Pullman, Washington SCS No. P-2327. Grown in 1945.

Bromus carinatus - Lot 32, progeny of native seed from near Enterprise, Utah. Grown in 1949.

Bromus inermis - Lot 47, Lincoln, progeny of certified seed. Grown in 1950.

Legumes

Astragalus cicer - Lot 9, Pullman, Washington SCS No. P-498. Grown in 1946.

Astragalus falcatus - Lot 11. Grown at SCS Nurseries in Bellingham Nursery. Received in 1948.

Lathyrus sylvestris - Lot 5, Pullman, Washington SCS No. P-27. Received in 1949.

Lotus corniculatus - Lot 5, Pullman, Washington SCS No. P-735. Received in 1949.

Medicago falcata - Lot 1A. Grown in 1947. Progeny of seed obtained from University of Alaska.

Medicago sativa - Lot Megl B. Progeny of A169, grown in 1950.

Medicago sativa - Lot 7, Ladak, Kelley Western Seed Company, certified. Grown in Idaho in 1945.

Medicago sativa - Lot 14, Rhizoma, Northrup, King and Company, Lot N431. Grown in New Mexico in 1949.

Vicia tenufolia - Lot 6, Pullman, Washington SCS No. P-692. Grown in 1948.

The advantages of grass-legume mixtures for conservation work and for pasture mixtures on farmland in sub-humid areas and under irrigation have long been recognized. However, little work has been done on grass-legume mixtures for western rangelands. Many of the legumes suited for irrigated land will not grow on the more arid rangelands. Many of these legumes have a single taproot which is easily destroyed by gophers or other digging animals, killing the plant.

This study is located on a small plot in the mountain brush type in Ephraim Canyon. Elevation is about 7,200 feet and annual precipitation is about 18 inches. The soil is a silt loam from limestone origin. The study site was cleared prior to planting. During the spring of 1950 the study area was burned. Stumps and remaining shrubs were cleared by disking and hand grubbing.

Prior to burning the vegetative cover was primarily big sagebrush interspersed with small patches of oak and snowberry. A few remnants of Agropyron spicatum, Sitanion hystrix, Oryzopsis hymenoides, and Lupinus could be found under the shrubby species. Bromus tectorum and other annuals were abundant in the openings.

An area 80 x 90 feet was divided into 4 equal blocks and each block was divided into 4 sub-blocks. Each sub-block contains 9 plots which are 5 feet wide and 10 feet long. Three furrows 20 inches apart were made the length of the plots. Seed of 1 grass species was placed in all furrows at a rate of 8 to 10 pounds per acre. Seed of each of the 9 legume species was planted at a rate of 8 to 10 pounds per acre. Assignment of grass species to sub-blocks was at random and placement of legume species within a sub-block is at random. Seed was then covered with soil to a depth of 3/4-inch and the soil was firmed.

During the period 1950 to 1953 the area was poisoned and trapped to keep pocket gophers and digging animals out of the study area. During the next 3 years this area was poisoned at intervals but in general natural condition in respect to grazing use by animal life prevailed. In the early spring of 1957 all old herbage from previous years was removed from the area, pocket gophers were poisoned and trapped, and a rabbit and deer exclosure was constructed around the study. Plant numbers and yield have been taken in 1951, 1952, 1953, and 1957. In 1957 the number of legume plants in each plot was counted. The legume plants were hand clipped on each plot and the grass was then mowed with a scythette. The legume and grass herbage was individually sacked and green weights were taken. Air dry weights were taken on all samples in mid-September. Oven dry weights were taken on selected samples.

Analysis of data has not been completed at this time but the following conclusions can be made. Of the four grass species used, mountain brome was most compatable with the legume species used. However, this short-lived grass had largely died out by 1957. Herbage production of legumes was smallest when grown with intermediate wheatgrass, figures 4 through 7. Legumes growing with crested wheatgrass and smooth brome produced similar yield. The strains of alfalfa were superior in both number and herbage production to other species, but Astragalus cicer also made a good showing. Astragalus falcatus and Medicago produced fair stands. Lathyrus sylvestris, Lotus corniculatus and Vicia tenufolia failed to produce fair stands in mixtures with these grasses on the mountain brush site.

Figure 4 .—A general view of the various legumes growing in mixture with intermediate wheatgrass in Block 4 on August 1, 1957.

Figure 5 .—A general view of the various legumes growing in mixture with crested wheatgrass in Block 4 on August 1, 1957.

Figure 6 .--A general view of the various legumes growing in mixture with mountain brome in Block 4 on August 1, 1957.

Figure 7 .--A general view of the various legumes growing in mixture with smooth brome in Block 4 on August 1, 1957.

III. CRc6-3: ESTABLISHMENT PRACTICES FOR REVEGETATION OF RANGE AREAS IN THE WEST

Suitable establishment practices are necessary for consistently successful and effective revegetation of depleted ranges on which the present plant cover is not adequate for soil protection or is of low forage values. The upper Colorado River Basin development provides for rehabilitation of this rangeland. This expanding reseeding program is moving work into the extremes of climate and soils on which little is known about reseeding. This magnifies the importance of "know-how" in restoring the vegetation cover. Low precipitation, dry summers, sandy soil, acid soil, steep slopes and rough terrain are some of the factors which require special consideration.

III-A. SEED GERMINATION UNDER CONTROLLED CONDITIONS

III-A-1. Behavior of seeds, partially germinated seeds and seedlings of four species at near freezing temperatures (0-1°C.) for various periods of time

This study was established to provide information on behavior and ability of grass seeds and seedlings to survive for various periods under near freezing temperature similar to those existing under a deep winter snow pack. Four species adapted to high elevations were selected and used in this test. Pertinent information on these seed lots follows: Agropyron trachycaulum, native strain harvested in Ephraim Canyon at 9,400 feet in fall of 1955; Arrhenatherum elatius, grown in Virginia in 1955, Snelson Seed Co., Atlanta, Georgia, Lot 633; Bromus carinatus, collected on Sonora Pass near Sonora, California, elevation 9,400 to 9,600 feet in the fall of 1955; Bromus inermis, certified Manchar smooth brome No. 103019, grown in Oregon in 1952.

One hundred seeds of each species were planted in plastic boxes approximately 4 inches wide, 4½ inches long and 1½ inches high containing ½ inch of silica sand. The sand was moistened on all lots except where dry seed was held as a control or check for the moistened lots. The sand was moistened until a slight film of water was visible in the lower corner when the box was tipped at 45° (approximately 22% moisture by weight). All boxes were then covered with self-sealing lids. Boxes were then placed in a germinator for various periods of time at alternating temperatures of 28°C. for 8 hours and 20°C. for 16 hours. All samples held in the germinator for less than 8 hours were held at 28°C. Boxes were then placed in a constant temperature cabinet at 0-1°C. for various periods and then placed in a germinator at alternating temperatures of 28°C. for 8 hours and 20°C.

for 16 hours until germination was complete. The various treatments applied are shown below.

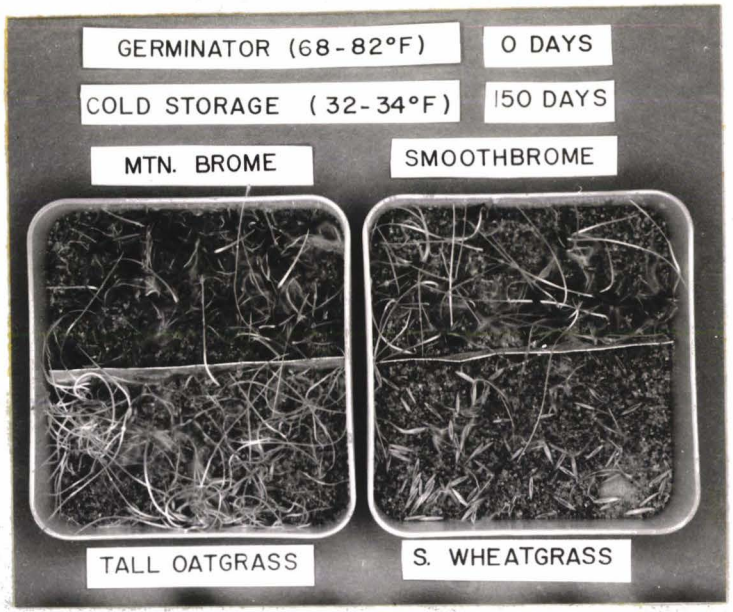
Moisture	Time at 28°C.-20°C.	Days at 0-1°C.	Complete Germinator 28°C.-20°C.
None	None	35,70,150 and 300	Yes
24%	None	35,70,150 and 300	"
24%	3 hours	35,70 and 150	"
24%	6 hours	35,70 and 150	"
24%	12 hours	35,70 and 150	"
24%	1 day	35,70 and 150	"
24%	2 days	35,70 and 150	"
24%	4 days	35,70 and 150	"
24%	8 days	35,70 and 150	"

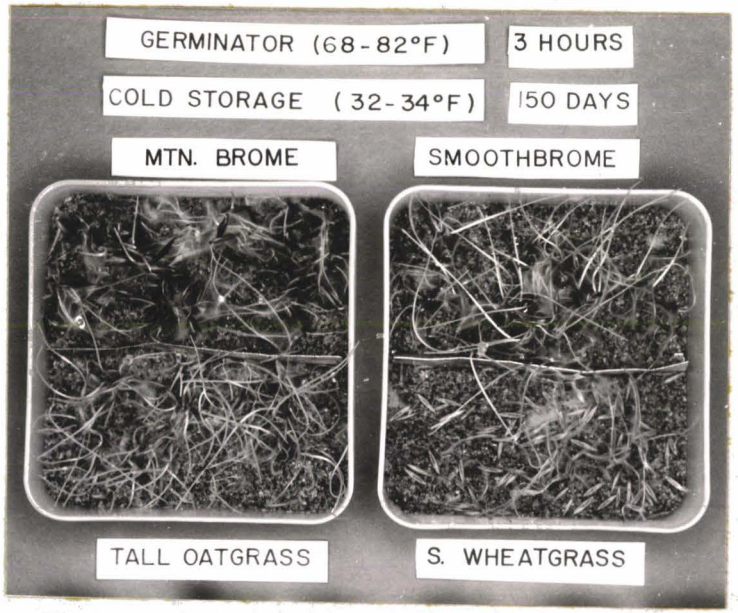
Average percent germination for two replications when seeds were removed from the germinator after various periods of time and subsequent germination near freezing temperature for 35, 70 and 150 days are shown in table 1. No damage was visible when seeds or seedlings were removed from the low temperature cabinet after 150 days (figs. 8, 9, 10 and 11). Complete or final germination percentages for seeds of these four species are shown in table 2. Average length of roots and shoots in milimeters for all seeds that had germinated on the prescribed day are shown in table 3. Seeds of species placed in the constant temperature cabinet on July 10, 1957 germinated and the seedlings are still vigorous after 270 days. These seeds and seedlings will be held at this temperature at least until May 5, 1958 or total of 300 days before they are removed.

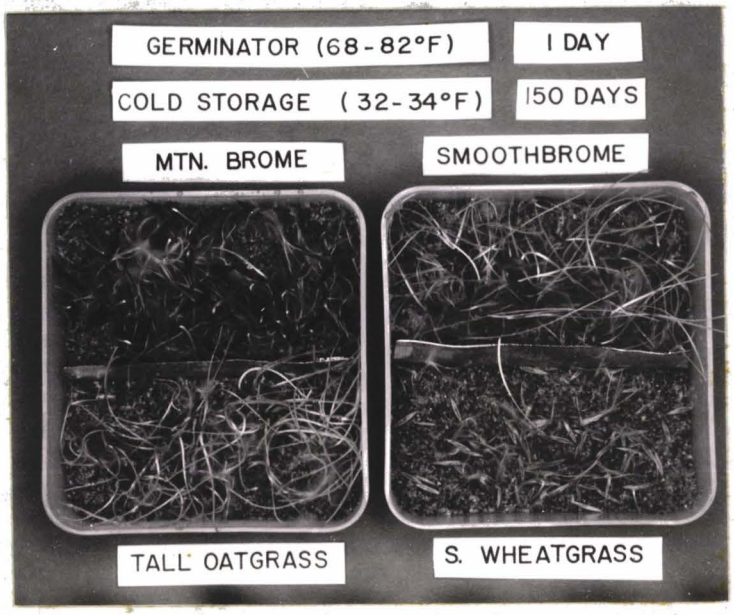
Table 1. Percent germination when seeds were in the germinator for various periods and subsequent germination at temperatures of 0 to 1°C. after 35, 70, or 150 days

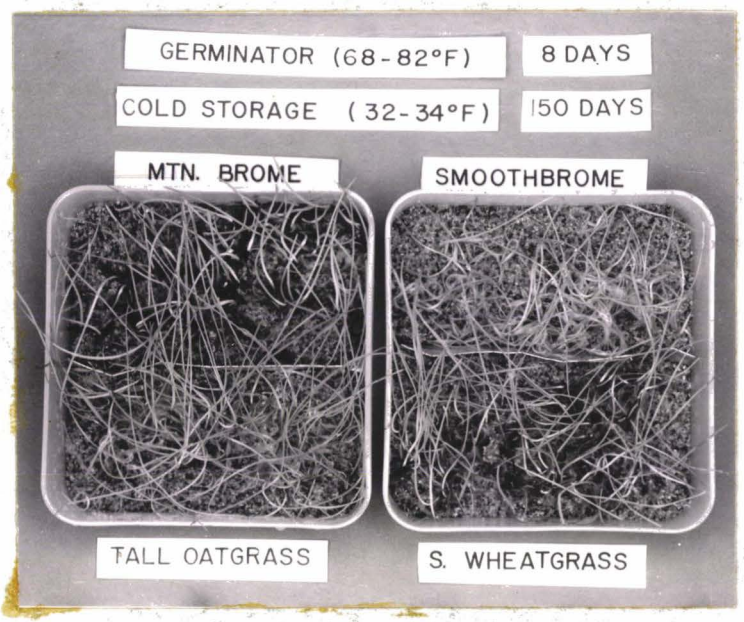
Partial 1/ Germination Treatment	Number of Days at Low Temperature (0 - 1°C.)																			
	Slender Wheatgrass					Tall Oatgrass					Mountain Brome					Smooth Brome				
	0	35	70	150	Ave	0	35	70	150	Ave	0	35	70	150	Ave	0	35	70	150	Ave
None - Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
None	0.0	0.0	4.0	27.0	10.3	0.0	0.0	65.0	94.0	53.0	0.0	0.0	73.0	92.0	55.0	0.0	2.5	55.5	86.0	44.2
3 Hours	0.0	0.0	2.5	26.5	9.7	0.0	5.5	86.0	95.0	62.2	0.0	0.0	76.0	92.0	56.0	0.0	7.5	52.5	82.5	47.5
6 Hours	0.0	0.0	4.5	33.5	12.7	0.0	9.0	84.5	97.0	63.5	0.0	2.5	89.5	93.5	61.8	0.0	12.5	80.5	80.5	57.8
12 Hours	0.0	0.0	0.5	50.0	16.8	0.0	27.5	87.5	95.0	70.0	0.0	19.5	87.5	90.5	65.8	0.0	9.0	82.5	91.0	60.8
1 Day	0.0	0.0	9.0	58.5	22.5	0.0	42.0	61.0	95.5	66.2	0.0	14.0	76.0	94.5	61.5	3.5	50.5	86.5	96.5	77.8
2 Days	5.5	8.0	44.5	79.0	43.8	28.3	76.0	88.5	96.0	86.8	0.2	16.5	81.0	96.0	64.5	42.3	79.5	91.5	95.5	88.8
4 Days	31.2	46.0	60.0	79.5	61.8	80.5	89.5	91.0	96.0	92.2	26.5	74.5	83.0	90.5	82.7	94.7	93.5	92.5	96.5	94.2
8 Days	71.2	85.5	77.0	90.5	77.7	85.0	90.5	85.5	93.5	89.8	77.5	81.5	87.0	91.0	86.5	93.7	95.0	91.5	96.5	94.3
Complete 2/	91.2	-	-	-	-	89.2	-	-	-	-	92.8	-	-	-	-	93.8	-	-	-	-

1/ Period of time seeds were in germinator at alternating temperatures of 20 - 28°C. prior to low temperature treatment.
2/ Complete germination tests with 6 replications of 100 seed of each species at alternating temperatures (20 - 28°C.) at the beginning of the study.









Figures 8 to 11.—Length of roots and shoots of 4 species after storage at 32 - 34°F. (0 - 1°C.) for 150 days following various pre-germination treatments.

Table 2 . Complete germination in percent for seed of four species after various partial germination treatments followed by storage at low temperatures (0 - 1°C.) for 35, 70, or 150 days and returned to the germinator until all viable seeds had germinated

Partial 1/ Germination Treatment	Number of Days at Low Temperatures (0 - 1°C.)															
	Slender Wheatgrass				Tall Oatgrass				Mountain Brome				Smooth Brome			
	35	70	150	Ave	35	70	150	Ave	35	70	150	Ave	35	70	150	Ave
None - Dry	95.5	96.0	94.5	95.3	88.5	86.0	91.0	88.5	92.5	95.5	93.7	93.9	95.5	93.5	96.2	95.1
None	85.0	92.0	95.5	90.8	84.5	92.0	95.0	90.5	90.0	92.5	94.5	92.3	92.5	92.0	98.5	94.5
3 Hours	95.5	94.0	93.5	94.3	83.5	88.0	96.0	89.2	90.0	95.0	93.0	92.7	94.0	95.5	95.0	94.8
6 Hours	91.0	92.0	94.5	92.5	87.5	89.0	97.5	91.3	93.5	90.0	95.5	93.0	91.5	95.0	96.0	94.2
12 Hours	95.0	97.5	96.5	96.3	83.0	91.0	95.0	89.7	91.5	92.5	92.5	92.2	95.0	92.0	98.5	95.2
1 Day	85.5	95.0	97.5	92.7	91.0	91.5	95.5	92.7	93.0	94.0	95.5	94.2	97.0	97.0	98.5	97.5
2 Days	94.5	94.5	97.5	95.5	90.5	93.0	96.5	93.3	90.5	92.0	97.0	93.2	95.0	95.5	96.0	95.5
4 Days	90.0	95.5	96.0	93.8	92.5	92.5	96.0	93.7	95.0	95.5	95.0	95.2	96.0	95.0	96.5	95.8
8 Days	93.5	92.5	96.0	94.0	87.0	95.5	94.5	92.3	87.5	93.5	93.5	91.5	97.5	94.5	98.0	96.7
Average	91.7	94.3	95.7	93.9	87.6	90.9	95.2	91.2	91.5	93.4	94.4	93.1	94.9	94.4	97.0	95.4
Complete 2/	-	-	-	91.2	-	-	-	89.2	-	-	-	92.8	-	-	-	93.8

1/ Period of time seeds were in germinator at alternating temperatures of 20 - 28°C. prior to low temperature treatment.

2/ Complete germination tests with 6 replications of 100 seed of each species at alternating temperatures (20 - 28°C.) at the beginning of the study.

Table 3 .--Average length of shoot and root in millimeters after various partial germination treatments and subsequent growth at 0 - 1°C. for 35, 70, or 150 days

Partial 1/ Germination Treatment	Number of Days at Low Temperatures (0 - 1°C.)											
	Slender wheatrass			Tall oatgrass			Mountain brome			Smooth brome		
	35 mm	70 mm	150 mm	35 mm	70 mm	150 mm	35 mm	70 mm	150 mm	35 mm	70 mm	150 mm
None - Dry												
Shoot	0	0	0	0	0	0	0	0	0	0	0	0
Root	0	0	0	0	0	0	0	0	0	0	0	0
None												
Shoot	0	0	25	0	2	35	0	2	30	0	4	40
Root	0	4	20	0	16	45	0	16	20	1	12	50
3 Hours												
Shoot	0	1	20	1	6	40	0	2	20	0	3	35
Root	0	6	25	3	18	55	0	18	25	1	22	50
6 Hours												
Shoot	0	1	30	1	4	35	0	2	25	1	2	40
Root	0	5	22	2	23	55	1	20	30	3	20	50
12 Hours												
Shoot	0	1	35	2	8	40	0	2	30	1	4	45
Root	0	5	25	4	16	50	2	18	30	2	24	62
1 Day												
Shoot	0	1	30	2	10	40	0	2	30	2	15	35
Root	0	7	30	6	26	60	4	20	30	6	23	65
2 Days												
Shoot	1	2	28	4	20	50	1	5	30	4	21	40
Root	4	16	30	14	28	60	8	21	30	12	26	65
4 Days												
Shoot	4	20	30	22	40	40	3	14	30	20	32	45
Root	11	25	40	35	42	65	11	22	38	22	42	65
8 Days												
Shoot	35	40	42	55	56	60	28	35	50	40	50	55
Root	32	37	42	38	40	75	40	42	55	38	48	65

1/ Period of time seeds were in germinator at alternating temperatures of 20 and 28°C. prior to low temperature treatment.

III-A-2. Behavior of seed of selected species placed on moist sand at near freezing temperatures (0-1°C.)

This study was established to provide additional information on minimum time for seed germination and rate of growth of root and shoot (radicle and coleoptile) at near freezing temperatures. The need for this study was indicated by the preceeding study on seed behavior after various partial germination treatments prior to placement of seeds at near freezing temperature. This study demonstrated that seed had germinated at the low temperatures but observations were only made after 35, 70, and 150 days at this temperature.

Two separate tests have been made. The first test was made with the four seed lots used in the partial germination study described in section III-A-1. The second study was with the seven species used in the germination study at near optimum temperatures in the laboratory (section III-A-3) and the study on seed behavior under natural conditions at three locations in the field (section III-B-4).

In the first study seed of the following four species were used: Native slender wheatgrass - collected on high elevations in Ephraim Canyon in 1955. Tall oatgrass - grown in Virginia in 1955. Mountain brome - harvested in the fall of 1955 at 9,200 - 9,600 feet near Sonora, California. Manchar smooth brome - grown in Oregon in 1952.

Seeds of the four species were placed on moist sand in small plastic boxes with self-sealing lids. Each box contained 50 seeds of each species. All boxes were placed in the constant temperature cabinet and a temperature between 0 and 1°C. was maintained throughout the study period.

Counts were made on number of seeds starting to germinate at intervals and maximum and average length of radicle and coleoptile were determined. Protrusion of the tip of radicle or coleoptile was used as criteria to define beginning of germination. Care was taken to keep seed at near freezing temperatures even while observations were being made. One series with 10 replications was placed in the low temperature cabinet on September 26, 1957. Two additional tests with 5 replications each were established on October 26, and November 20, 1957. There is very close agreement between these three separate tests on percent germination and length of radicle and coleoptile by days after establishment. Average numbers of seeds showing radicle or coleoptile for the test with 10 replications, established on September 26, are shown in table 4. In addition 3 replications of each species were placed in a germinator at 28°C. for the first 8 hours and 20°C. for the last 16 hours in each day at the same time seeds were first placed in the low temperature cabinet on September 26, 1957. Percent germination for these 4 seed lots after 6 weeks were as follows:

Species	Percent Germination
Native slender wheatgrass	91.0
Tall oatgrass	87.7
Mountain brome	91.7
Manchar smooth brome	97.7

Fifty seeds of 7 species including the same lots of Manchar smooth brome and tall oatgrass were placed on moist silica sand in small plastic boxes with self-sealing lids. Each species was replicated 4 times in this

Table 4.—Percent germination with seeds of seven species placed on moist sand and held at a constant low temperature of 0 - 1°C.

Species	Number of Days															
	21	29	39	55	62	68	74	82	88	96	103	110	117	132	146	182	195
Slender wheatgrass	0.0	0.0	0.0	0.0	0.2	0.2	0.4	1.4	1.6	2.0	2.0	2.4	2.4	5.0	6.4	8.0	8.0
Tall oatgrass	0.0	0.0	21.2	59.4	71.4	76.6	80.8	85.0	86.0	87.8	88.4	88.4	89.2	89.2	89.2	89.2	89.2
Mountain brome	0.0	0.0	5.2	65.2	79.2	82.6	84.6	86.8	86.8	87.8	89.0	89.4	89.8	90.2	90.2	92.0	92.4
Smooth brome	0.0	2.6	15.8	27.2	37.0	43.4	52.2	59.4	59.6	64.8	72.4	73.6	74.0	76.2	77.0	77.4	77.6

test. These species are as follows: Crested wheatgrass, Nordan PC 31968, Mandan, N. Dakota, probably grown in 1953. Intermediate wheatgrass, Northrup King Company #D6-1 grown in Washington. Native slender wheatgrass, harvested in fall of 1957 at 9,600 feet in Ephraim Canyon. Tall oatgrass, Snelson Seed Company, Lot 633, Atlanta, Georgia, grown in Virginia in 1955. Native mountain brome, harvested in Ephraim Canyon at an elevation of 9,200 feet in the fall of 1957. Manchar smooth brome certified No. 103019, grown in Oregon in 1952. Red fescue, Northrup King, #6178, grown in Oregon.

Average percent of plants with radicle or coleoptile visible on various dates are shown in table 5. Maximum and average length of radicle and coleoptile (root and shoot) in milimeters on the same dates are shown in table 6.

Table 5 .—Percent germination with seeds of seven species placed on moist sand and held at a constant low temperature of 0 - 1°C.

Species	Number of Days									
	15	18	21	33	41	48	63	72	85	100
Crested wheatgrass	0.0	0.5	4.5	49.0	58.5	73.0	80.0	82.5	84.0	84.0
Intermediate wheatgrass	0.0	0.0	0.0	0.5	1.5	4.5	9.5	12.5	28.5	36.5
Slender wheatgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tall oatgrass	0.0	0.0	0.0	0.0	0.0	4.0	22.0	37.5	62.0	72.5
Mountain brome	0.0	0.0	0.0	0.0	0.0	0.0	4.0	5.0	12.5	15.0
Smooth brome	0.0	0.0	1.0	5.5	5.5	10.0	22.0	33.5	49.0	60.0
Red fescue	0.0	0.0	0.0	0.0	0.0	0.0	6.0	8.0	12.5	21.5

Table 6 .—Maximum and average length of shoot and root on seedlings of seven species placed on moist sand and held at a constant low temperature 0 - 1°C. for various periods of time

Species		Number of Days									
		15	18	21	33	41	48	63	72	85	100
		(Length in Millimeters)									
Crested wheatgrass											
Shoots	Max.	-	-	-	T	1	1	3	9	19	24
	Ave.	-	-	-	T	T	T	T	1	8	14
Roots	Max.	-	T	T	1	2	4	12	18	29	32
	Ave.	-	T	T	T	T	1	3	9	14	18
Intermediate wheatgrass											
Shoots	Max.	-	-	-	-	-	-	-	2	3	7
	Ave.	-	-	-	-	-	-	-	T	T	1
Roots	Max.	-	-	-	T	1	1	5	8	9	21
	Ave.	-	-	-	T	T	T	1	1	1	7
Slender wheatgrass											
Shoots	Max.	-	-	-	-	-	-	-	-	-	-
	Ave.	-	-	-	-	-	-	-	-	-	-
Roots	Max.	-	-	-	-	-	-	-	-	-	-
	Ave.	-	-	-	-	-	-	-	-	-	-
Tall oatgrass											
Shoots	Max.	-	-	-	-	-	-	T	2	4	5
	Ave.	-	-	-	-	-	-	T	T	1	2
Roots	Max.	-	-	-	-	-	1	3	10	14	19
	Ave.	-	-	-	-	-	T	1	1	2	9
Mountain brome											
Shoots	Max.	-	-	-	-	-	-	-	-	-	5
	Ave.	-	-	-	-	-	-	-	-	-	T
Roots	Max.	-	-	-	-	-	-	1	3	9	19
	Ave.	-	-	-	-	-	-	T	1	1	6
Smooth brome											
Shoots	Max.	-	-	T	T	T	T	2	2	3	6
	Ave.	-	-	T	T	T	T	T	T	T	1
Roots	Max.	-	-	-	1	1	1	3	5	12	17
	Ave.	-	-	-	T	T	T	1	1	2	6
Red fescue											
Shoots	Max.	-	-	-	-	-	-	-	-	1	3
	Ave.	-	-	-	-	-	-	-	-	T	T
Roots	Max.	-	-	-	-	-	-	1	1	3	8
	Ave.	-	-	-	-	-	-	T	T	T	1

III-A-3. Seed germination at near optimum conditions

A study was established to determine the minimum time required for seed germination to begin at alternating temperatures of 28°C. for 8 hours and 20°C. for 16 hours. Protrusion of the radicle tip or coleoptile tip has been used as criteria to define beginning of germination. Seeds of seven select species were used in this test. See section III-A-2, above, for pertinent information on these seed lots since they are the same as those used in the laboratory germination tests at near freezing temperatures and in the field seed behavior studies conducted at three locations in the winter and spring of 1958 under natural condition.

One hundred dry seeds of each species were placed on moist sand within small plastic boxes with self-sealing lids. The study was set up with four replications. Lids were placed on the boxes. Boxes were placed in a germinator at a temperature of 28°C. for the first 8 hours. Boxes were then moved to a temperature of 20°C. for the next 16 hours. These alternating temperatures were maintained throughout the study.

Observations were made every two hours for the first 12 hours and after 18, 24, 36, 48, 72, 96, 120, and 144 hours. Protrusion of the tip of the radicle or coleoptile was used to define the beginning of germination. Observations included determining the number of seeds that had started to germinate. The maximum length of the radicle (root) and coleoptile (shoot) and the average length of the radicle and coleoptile only on the seeds that had started to germinate was determined. The number of seeds that had started to germinate were also determined on the 7, 9, 12, 15, 20, 25, 30, and 45 day after the study was initiated. Percent germina-

tion of seven species by hours and by days are shown in table 7. Maximum and average length of the radicle and coleoptile during the first 144 hours (6 days) are shown in table 8. On the species and accessions tested the tip of the radicle was first visible on crested wheatgrass seed after 10 hours, smooth brome seed after 12 hours, intermediate wheatgrass seed after 18 hours, tall oatgrass and red fescue seeds after 24 hours, native mountain brome seed after 96 hours and native slender wheatgrass after 144 hours. The low germination for native mountain brome and native slender wheatgrass after 45 days is not a true indication of viable seed but rather an indication that after ripening processes have not been completed. Where these accessions have been subjected to moist cold conditions existing under the snow at Headquarters Station, percent germination has steadily increased. On April 7, 1958 germination of this slender wheatgrass was over 90 percent and percent germination for this mountain brome exceeded 85 percent.

Germination of both accessions will probably be 95 percent or better when the seeds have completed after ripening processes. Germination tests made on the seeds of native slender wheatgrass and native mountain brome harvested in the fall of 1957 have shown a gradual increase in percent germination as the seed aged. Test with seeds of slender wheatgrass harvested in the fall of 1955 show that slight changes in temperature or moisture may have a pronounced effect on the current germination of the seed.

Table [illegible].—Percent seed germination after various periods of time at 28°C. for the first 8 hours and 20°C. for the following 16 hours in each day

Species	Time In Germinator																	
	Hours											Days						
	8	10	12	18	24	36	48	72	96	120	144	7	9	12	15	20	25	30	45
Crested wheatgrass	0.0	0.5	1.2	15.2	28.0	49.8	56.8	69.5	74.5	77.5	78.2	80.2	82.0	82.2	83.2	84.5	85.0	85.0	85.2
Intermediate wheatgrass	0.0	0.0	0.0	7.8	15.2	32.0	45.8	69.0	82.0	87.0	91.0	91.2	92.8	93.0	94.2	94.8	95.0	95.0	95.0
Slender wheatgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.5	4.8	5.0	5.0	5.0	5.5	6.0	8.8
Tall oatgrass	0.0	0.0	0.0	0.0	1.8	22.0	35.5	50.2	64.0	69.5	72.0	73.8	75.2	76.5	77.5	83.5	83.5	83.5	83.5
Mountain brome	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	11.5	14.8	17.2	27.2	33.5	40.5	44.5	45.8	46.2	48.5
Smooth brome	0.0	0.0	1.8	8.5	21.5	45.0	59.8	73.0	84.2	85.0	85.0	89.2	90.0	90.0	91.0	91.0	91.2	91.2	91.2
Red fescue	0.0	0.0	0.0	0.0	6.5	31.2	54.5	75.0	85.0	91.2	92.2	92.8	94.5	94.5	95.5	95.5	95.8	95.8	95.8

Table 8 .—Maximum[1/] and average[2/] length of radicle or root and coleoptile or shoot after various periods of time (0 to 144 hours) at 28°C. for the first 8 hours and 20°C. for the following 16 hours in each day

Species		Hours in Germinator										
		8	10	12	18	24	36	48	72	96	120	144
		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Crested wheatgrass												
Radicle	Max.	-	T	T	1	2	4	9	22	28	36	42
	Ave.	-	T	T	T	T	1	1	8	14	19	24
Coleoptile	Max.	-	-	-	-	-	-	2	17	27	51	65
	Ave.	-	-	-	-	-	-	T	6	14	22	38
Intermediate wheatgrass												
Radicle	Max.	-	-	-	1	2	4	8	26	37	45	53
	Ave.	-	-	-	T	T	1	1	8	14	21	30
Coleoptile	Max.	-	-	-	-	-	-	3	11	19	31	40
	Ave.	-	-	-	-	-	-	T	3	9	18	24
Slender wheatgrass												
Radicle	Max.	-	-	-	-	-	-	-	-	-	-	8
	Ave.	-	-	-	-	-	-	-	-	-	-	4
Coleoptile	Max.	-	-	-	-	-	-	-	-	-	-	-
	Ave.	-	-	-	-	-	-	-	-	-	-	-
Tall oatgrass												
Radicle	Max.	-	-	-	-	T	1	3	18	24	38	45
	Ave.	-	-	-	-	T	T	T	4	10	17	23
Coleoptile	Max.	-	-	-	-	-	-	2	6	18	36	42
	Ave.	-	-	-	-	-	-	T	1	6	17	22
Mountain brome												
Radicle	Max.	-	-	-	-	-	-	-	-	10	16	25
	Ave.	-	-	-	-	-	-	-	-	2	4	12
Coleoptile	Max.	-	-	-	-	-	-	-	-	-	-	-
	Ave.	-	-	-	-	-	-	-	-	-	-	-
Smooth brome												
Radicle	Max.	-	-	T	T	1	3	7	23	28	34	37
	Ave.	-	-	T	T	T	1	1	10	16	17	23
Coleoptile	Max.	-	-	-	-	T	1	2	13	18	25	36
	Ave.	-	-	-	-	T	T	T	4	8	13	22
Red fescue												
Radicle	Max.	-	-	-	-	T	1	2	8	12	25	28
	Ave.	-	-	-	-	T	T	T	1	6	12	18
Coleoptile	Max.	-	-	-	-	-	T	T	3	10	18	27
	Ave.	-	-	-	-	-	T	T	T	3	10	18

1/ Maximum length of root or shoot in the four replications.

2/ Average length of roots or shoots only for the seeds that had started to germinate.

III-B. SEED GERMINATION STUDIES UNDER NATURAL CONDITIONS IN THE FIELD

III-B-1. Seed behavior under snow in the spruce-fir type in 1956-1957

On November 2, 1956 a study was established at an elevation of 9,950 feet on Philadelphia Flat. The original purpose of this study was to determine the behavior of seeds during rapid spring snowmelt.

Spring plantings at high elevation have usually been successful. Where failures have occurred the reasons have usually been obvious. Fall plantings at high elevations in central Utah have usually been successful but on some local areas and in other parts of the Intermountain Region fall plantings have failed repeatedly. The reasons for these failures have been obscure since species used, seed quality, depth of planting, competition, soil moisture and similar factors do not appear to be the cause of these failures. An examination of some of these plantings has shown that good stands are frequently growing on rocky ridges and south or west facing slopes when poor stands are growing on the deep fertile soils in the swales and valleys. High water marks and other signs observed in the spring of 1956 indicate that water reached a depth in excess of 3 and 5 inches, respectively, on two separate test areas. Snow survey notes substantiate these findings and indicate that melted snow water may accumulate under the snow under certain conditions.

Cloth bags containing 100 seeds of Manchar smooth brome or 100 seeds of tall oatgrass were planted on Philadelphia Flat. Bags were placed under ½-inch of soil and the existing snow cover of about 14 inches was replaced. Seeds were not moistened prior to planting. The soil under the snow was quite moist and free of frost. Sacks containing seeds were

placed at three locations approximately 100 feet apart with five separate planting sites at each location. Two sacks containing smooth brome and two sacks containing tall oatgrass were planted together. To facilitate location of bags, stakes 5 feet long were set out in the shape of a wheel with 5 spokes. The hub stake was placed 20 feet from the terminal stakes. Seeds were placed at a midpoint (10 feet) between the hub stake and each terminal stake. This arrangement was used so that the seed could be easily located and so that removing one seed sample would not disturb the snow over the remaining seeds. Seed samples were removed at random.

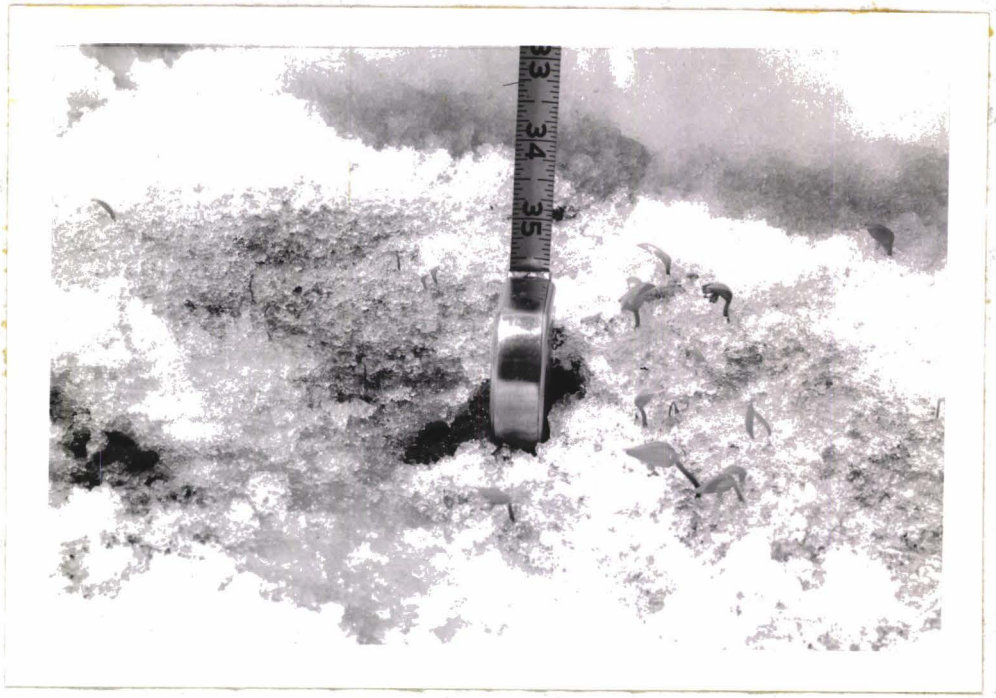
Germination of smooth brome was 95.4% and germination of tall oatgrass was 12.6%. Attempts to obtain seed of tall oatgrass with high percent germination before the planting date failed and the old seed was planted to determine the behavior of seed with low viability.

This area was first visited in the spring on May 15, 1957. Snow was approximately 5.5 feet deep and stakes could not be located. A second visit was made on May 26, but recent storms had increased the snow pack to a depth of 6.5 feet. Stakes could not be located but a pit was made in the snow. The soil was ice-free and moist. Some native mountain brome plants were ½ to 1½ inches high and color of the leaves ranged from a near white to yellow-green. Seeds of several weeds had germinated and the cotyledons had extended a short distance up into the snow. On June 3 snow had started to thaw but stakes could not be located because snow depth was still over 6 feet deep. Soil was thawed and very moist.

On June 7 the snow depth was about 5 feet deep. The tip of one stake was located and the first seed samples were removed. Seed germination had occurred prior to this date. Roots and shoots of smooth brome and a few tall oatgrass plants were protruding through the cloth bags but some of the smooth brome and most of the tall oatgrass seeds were black and appeared dead. Cloth bags, containing the seed, were very rotten and had to be removed with care. Cloth bags were then placed in plastic bags and packed in snow to hold temperatures at near freezing until germination percent and other observations could be made in the laboratory. On this date an ice crust was observed under the snow and just above the soil and germinated seedlings and established perennial plants were often extending through this crust of ice. By 2 p.m. the bottom of the pits made on May 26 and June 3 were flooded with water.

The second sample of seeds was removed from Philadelphia Flat on June 13 and snow depth was 32 to 38 inches. Soil appeared to be at or near saturation. A layer of ice about ½ inch thick was usually found at or near the soil surface. Many seedlings of native plants, annuals and perennials had germinated under the snow. Spring beauties had penetrated from 1 to 2 inches up into the snow.

On June 17 the third seed sample was taken. Snow depth was still between 32 and 37 inches on the study sites due to 16 inches of new snow. Snow was melting very rapidly in the afternoon of this date. Spring beauties were protruding up into the snow 1 to 3 inches (figs. 12 and 13). Figures 14 and 15 show the cloth sacks containing smooth brome and tall oatgrass after the soil covering had been removed. These photos also show the saturated soil, seedlings of native plants and one photo shows a plant of native mountain brome with leaves up to 3 inches long.



Figures 12 and 13.—Spring Beauties were protruding up into the snow pack from 1 to 3 inches on June 17, 1957. The upper photo shows pit made in the snow pack and the lower photo shows a close-up of the bottom of this pit (B57-41 and B57-42).

Figures 14 and 15.—These photos taken in the bottom of a snow pit 37 inches deep show cloth sacks containing smooth brome and tall oatgrass after the soil covering had been removed. These photos also show the wet saturated soil, seedlings of native plants and the lower photo shows a plant of native mountain brome with leaves up to 3 inches long (B57-38 and B57-39).

On June 20 snow depth averaged 22 to 26 inches on the study area. A layer of ice was observed at the soil surface in the morning. Spring beauties and dogtooth violets were turning green. Spring beauties were 1½ to 3 inches high, in bud and ready to bloom. Some of the dogtooth violets were protruding up in the snow more than 5 inches. By noon free water was coming into the pits.

On June 24 snow depth varied from 13 to 16 inches deep on the study area. A heavy ice layer about ½ inch thick was found just above the soil surface but the soil was very wet below the ice. By mid-afternoon water was from ½ to 3 inches deep on the study area.

On June 26 snow depth ranged from 0 to 11 inches and the west plot area was free of snow. Water depth on the east portion of the study area and most of Philadelphia Flat ranged from 2 to 7 inches deep and many of the native plants were growing through the snow. Figures 16 and 17 show how rapidly the snow melted from the surrounding area. The upper photo was taken on June 13 and the lower one on June 26.

The last seed samples were taken from the study area on June 28, 1957. Snow had disappeared from the plot area but soil was still wet at the soil surface.

Cloth bags maintained at near freezing temperature were taken to the laboratory where seeds were examined. Records were made of the number of seeds with radical or coleoptile visible as soon as possible and this number is considered to be the number that had germinated when the seeds were removed from the soil. Seeds were placed on moist sand in Petri dishes and placed in a germinator at alternating temperatures of 28° C. for 8 hours and 20° C. for 16 hours. Additional counts were made to determine rapidity of additional germination, normal development of roots and shoots, fungi growth and other factors.

Figures 16 and 17.—These photos compare the snow cover at the head of Ephraim canyon on June 13 and just 13 days later on June 26, 1957 (B57-35 and B57-45).

Many of the seeds of smooth brome and nearly all tall oatgrass seeds appeared to be dead when removed from the soil. Many seeds were dark brown or black. Some smooth brome seeds with roots up to 3/4 of an inch long appeared to be dead when they were removed from the soil. Table 9 shows the percent germination when seeds were removed from the soil, final percent germination (total number that started to germinate), and the percent that produced normal seedlings.

Table 9 .--Seed germination under snow on Philadelphia Flat and in the germinator.

1957 Date Removed	Percent Germination						Depth of snow inches	No. of Reps.
	Smooth Brome			Tall Oatgrass				
	Initial[1]	Final[2]	Normal[3]	Initial[1]	Final[2]	Normal[3]		
June 7	27.1	61.8	57.3	None	0.3	0.3	60-65	2
June 13	23.9	60.9	53.2	None	0.2	0.2	32-38	6
June 17	24.1	60.0	54.5	None	None	None	32-37	6
June 20	20.6	52.0	45.1	None	None	None	22-26	4
June 24	16.5	41.7	35.9	None	None	None	13-16	2
June 26	17.2	56.3	52.5	None	None	None	0-11	3
June 28	23.0	57.4	49.6	None	None	None	None	4

1/ Seeds with radicle or coleoptile visible when removed from snow.

2/ Seeds that started to germinate either under snow or in the germinator but may not have developed a healthy root or shoot.

3/ Seeds that developed a healthy or normal root and shoot.

III-B-2. Seed behavior under snow in the aspen-fir type during the winter and spring of 1957

Additional plantings of seed in small cloth bags were made under 1/2-inch of soil and the existing snow cover on November 30, 1956 and January 4, 1957. Plantings were made at Headquarters Station, elevation 8,850 feet. Prior to planting on November 30, 100 seeds of Manchar smooth brome and 100 seeds of tall oatgrass were placed in cloth bags, about 4x5 inches in size. Average germination of this smooth brome seed was 95.4 percent and average germination of the Tualatin tall oatgrass (F.C. 29,367) was 12.6 percent. Attempts to obtain seed of tall oatgrass with a high percent germination before the planting date failed and old seed on hand was planted to determine the behavior of seed with low viability. Part of this seed was placed in a germinator for 8 hours at 30°C. and 20°C. for 24 hours. At the end of this period the tip of the radicle was visible on 23 percent of these seeds. The remainder of the seed was moistened and held at 20°C. for 2 hours prior to planting. Seed was planted at 5 separate locations with 5 replications (20 sacks) at each location. On this date the average snow depth was 14 inches. The soil under the snow was frozen to a depth of approximately 1 inch. The frozen soil was chopped out and sacks were placed on the native soil. The sacks were then covered with 1/2-inch of dry soil and the original snow cover was replaced. All sacks placed in each hole were tied onto a single strong cord which was fastened to a nearby pole so that the seed could be easily located.

Sacks containing additional seeds of Manchar smooth brome and seeds of a lot of tall meadow oatgrass (commercial, grown in Virginia, Snelson Seed Company, #633) with a percent germination of 89.2 percent were planted

in five nearby but separate locations on January 4, 1957. Seeds were moistened and held at 20° C. for 2 hours just prior to planting. On this date the soil was frozen to a depth of 1/4 to 1/2 inch. Snow depth was 31 inches. The frozen soil was chopped out and sacks were placed on the moist native soil and covered with 1/2 inch of dry soil. Sacks from one location were removed during the first week of each month, beginning in January 1957. Sacks were removed from the soil and placed in plastic bags and taken to the laboratory. Seeds were examined for germination, fungi, and other damage and placed on moist sand in Petri dishes. Seed was placed in a germinator at alternating temperatures of 20° C. for 16 hours and 28° C. for 8 hours.

Seed samples were taken on January 4, February 4, March 5, April 10, and May 13, 1957. As mentioned above the soil was frozen to a depth of about 1 inch on November 30, 1956 and to about 1/2 inch on January 4, 1957 and partially frozen on February 4, 1957. On March 5 the sacks were in moist soil but a slight ice crust could be seen at the surface of the soil.

On March 5 the string and cloth sacks were quite rotten due to fungi and other organisms. On this date the radicle had been frozen on most of the pre-germinated smooth brome seeds that had started to sprout. However, on some of these the coleoptile or shoot was visible and did not appear to be damaged and the tip of the radicle and coleoptile was visible on a few of the smooth brome seeds which were only moistened prior to planting.

On the seed lots removed on February 4 many of the seeds that had started to germinate in the germinator prior to planting appeared dead. On these pre-germinated seeds the root tip or radicle that emerged in the germinator usually disintegrated but on some a secondary root was produced and a shoot would be developed without producing another root.

On April 10, 1957 the snow depth was 90 inches. The soil was thawed and leaves on the native mountain brome was yellow-green and up to 2 inches in length. Some of the smooth brome and tall oatgrass seeds were germinating and growing. Some smooth brome seed had produced roots up to 3/4 of an inch in length.

The last lots of smooth brome and tall oatgrass were removed on May 13, 1957. The soil was free of ice and the surface soil was near saturation under the snow pack of 46 inches. Native forbs and grasses were beginning to grow under the snow. Seeds of both smooth brome and tall oatgrass were germinating and growing quite rapidly under the snow. Germination percentage at the time seed samples were removed from under the snow pack and after complete germination in the germinator are shown in table 10.

The old seed of Tualatin tall oatgrass appeared to be more subject to pathogen and unfavorable growing conditionsunder the snow in late spring at this site. Pre-germinated seeds that showed some injury to the root or shoot when the sacks were removed from the soil frequently developed a healthy seedling. On these pre-germinated seeds of smooth brome the shoot was frequently very slow to emerge from the coleoptile.

Table 10 .--Percent germination of seeds receiving various treatments when removed from under the snow at Headquarters Station and subsequent germination in the germinator

Species treatments	Dates seeds were removed from snow				
	Jan. 4	Feb. 5	Mar. 5	Apr. 10	May 13
Manchar Smooth Brome - Commercial		Germination 95.4%			
Pre-germination treatment planted November 30, 1956					
Under snow	0.0	0.0	2.8	6.8	6.1
Final	67.8	21.2	9.8	37.6	41.4
Control #1 planted November 30, 1956					
Under snow	0.0	0.0	1.5	12.2	12.2
Final	87.6	88.6	90.2	87.2	86.0
Control #2 planted January 4, 1957					
Under snow	-	0.0	1.2	9.6	12.4
Final	-	89.6	85.8	82.8	82.8
Tall Oatgrass Tualatin F.C. 29,367		Germination 12.6%			
Pre-germination planted November 30, 1956					
Under snow	0.0	0.0	0.0	0.0	0.0
Final	2.2	1.0	0.6	1.0	0.6
Control #1 planted November 30, 1956					
Under snow	0.0	0.0	0.0	1.6	0.4
Final	13.2	3.2	7.8	8.8	4.2
Tall Oatgrass-Commercial		Germination 89.2%			
Control #2 planted January 4, 1957					
Under snow	-	0.0	0.0	1.8	19.4
Final	-	69.2	77.6	51.4	67.8

III-B-3. The study of seed germination and behavior under winter snow and during rapid spring snowmelt during the spring of 1958

This study was established to provide additional information on the factors which may limit or curtail germination, emergence and establishment of common grasses from fall plantings at high elevations. The treatments, procedures, and methods are largely based on the studies conducted in the winter of 1956-1957 and spring of 1957 on this area and at the Headquarters Station.

The 1957 studies reported on in Sections III-A-1 and III-A-2 demonstrated that some seed of smooth brome had germinated and was growing under a snow cover of 74 inches at Headquarters Station prior to March 5, 1957. The approximate date of seed germination on Philadelphia Flat could not be determined because the area was not visited until May 15 and seed samples could not be located until June 7, when snow depth had decreased to about 5 feet and plot markers were located. These studies also demonstrated that viability of some of the remaining seeds had been reduced. This was especially noticeable on Philadelphia Flat where many of the remaining seeds were black and appeared to be dead.

Seeds of native mountain brome, collected at 9,000 feet in the fall of 1957 in Ephraim Canyon; native slender wheatgrass, collected at 9,400 feet in the fall of 1957 in Ephraim Canyon; Manchar smooth brome, certified, No. 103019, grown in Oregon; and tall oatgrass, grown in Virginia in 1955 were used in this study. One hundred seeds of a single species were placed in small cloth bags and the openings were closed and stitched. Bags were color coded with ink to insure species identification in the field.

The study area to be used was prepared during the late summer and fall of 1957. Gophers were trapped on the surrounding area during September and October. Three areas approximately 100 feet apart were staked out so that sacks could be located after snow covered the site. Center stakes with the tip 8 feet above the soil were placed in the middle of each area. These stakes were in line and formed a base line. Four radius stakes, 7 feet long, were placed 20 feet from each center stake on both sides of the base line and at an angle of 30 degrees from the base line. Thus two radius stakes and the center stake would be in line.

Four "planting" treatments were used in this study. These included planting in native soil, planting in sand pits placed in the soil, planting on sand mounds and planting in the snow, approximately 4 inches above the soil surface. Sand pits were made by removing native soil from an area 3 feet square and 5 inches deep and replacing it with builder's sand. Sand mounds were made by building a frame 3 feet square and 5 inches high out of galvanized wire screen supported by lath stakes at all corners and at intervals along the sides. This frame was filled with builder's sand. Wooden frames 2 feet square and 6 inches high were made without tops or bottoms to hold the sack of seed up in the snow. Ends of the frames were solid but the sides were partly open to allow lateral movement of snow by wind, gravity, and etc. Four nylon chords were stretched across the top of the frames and sacks were stitched to the chords.

Since the cotton sacks rotted away in the spring of 1957 making seed removal very difficult, plastic screen was placed below all cloth sacks at the time of planting. Sand and soil was scraped from the planting area to a depth of 2 centimeters. Strips of plastic screen 5 inches wide and 2 feet long were placed flat on the sand or soil. Sacks were then placed on the screen and the sand or soil which had been removed was placed on the sacks, making a soil or sand covering 2 centimeters thick. The four treatments within one sampling site were located between two adjoining radius posts and the center posts. Two of these treatments were between each radius post and the center post. One treatment in each pair was 7 feet from the center post and the other was 7 feet from the radius post. Location of the treatments at each sampling site will be at random.

Plantings were made on October 15, 1957. A snow blanket from 3 to 8 inches deep covered this area until October 23. In addition, a direct seeding of these species was made in furrows 40 feet long. Additional plantings will be made in the spring of 1958 as soon as the snow melts from the study area.

Heavy rain and snow storms during the period October 1 to October 23 resulted in puddling and soil saturation. Water up to 3 inches deep was observed in low areas and drainages. Infiltration rate of the soil appears to be very low. A heavy snow storm on October 23 put a permanent winter snow cover on this area. The last visit to this area in the fall of 1957 was made on October 29. Snow depth averaged 14 inches.

The soil was free of frost and appeared to be at or near saturation. "Free water traps" in this area were not filled with water on this date.

In summary, there are six sampling units in this study. Each sampling unit contains 4 treatment areas and each treatment area contains 12 sacks (3 replications x 4 species). Sampling units will be removed beginning about March 1. Other units will be sampled at monthly intervals until rapid spring snowmelt when weekly or bi-weekly intervals will be used. The exact sampling dates will be largely determined by weather condition and beginning of rapid spring snowmelt. Work on this study will be completed at the same time this area is visited to check the flooding under snow equipment.

The first samples were removed from this area on February 28, 1958 but seed germination and behavior will be reported after the work is terminated or in the 1958 Annual Report. Snow depth was 74 inches deep on February 28, 1958 and 96 inches deep on March 28, 1958.

III-B-4. Observations on seed germination and behavior of seven species under natural conditions at three field locations

This study is based on information obtained from field germination studies conducted at Philadelphia Flat and Headquarters Station in the fall of 1956 and winter and spring of 1957 as well as laboratory studies made in the summer and fall of 1957. See Sections III-B-1, III-B-2, and III-A-1 of this report for details.

The purpose of this study is to determine the relative behavior of seeds of seven grass species in relation to existing natural environmental condition at three locations during the fall, winter, and spring. Information on when seeds germimate, rate of growth in rootsand shoots, damage to seeds and seedlings by frost, damage to seeds by pathogens, and other factors is needed to better understand why fall plantings fail or succeed.

The sites used for this study arelocated in Sanpete County, with one area approximately 1 mile southeast of Ephraim, Utah. The other two areas are in the mountain brush type and aspen-fir type respectively in Ephraim Canyon. (1) The area near Ephraim, Utah is in the sagebrush type. It is located at an elevation of 5,500 feet on an alluvial fan formed by Ephraim Creek. Average annual precipitation is slightly less than 11 inches per year. Average frost free period for this site is approximately 120 days. Native vegetation of natural areas in this type is predominantly big sagebrush. Such species as Indian ricegrass, bluebunch wheatgrass, and western wheatgrass were reported to be abundant prior to heavy grazing use by livestock but now occur only in limited amounts. Cheatgrass and squirreltail are now the most abundant grass

species. Soils are a shallow loam of limestone origin. (2) The mountain brush site is located on a silt loam of limestone origin at an elevation of 7,200 feet. Average annual precipitation is about 18 inches and the frost free period is approximately 90 days. Native vegetation consists primarily of patches of gambel oak, interspersed with other shrubs such as big sagebrush, serviceberry, and mountainmahogany. A moderate number of grasses and weeds occur as an understory. (3) The aspen-fir site is located at an elevation of 8,850 feet on a clay-loam of limestone origin. The climate is characterized by a short favorable growing season with frequent frost occurring during the early late snow free periods. The dominant vegetation is scattered patches of aspen and fir. The understory is made up of snowberry and a mixture of mountain brome, slender wheatgrass, and broad leaved herbs.

Species used in this study and pertinent information on these seven species are listed below:

Nordan crested wheatgrass, P.C. 31968, grown at Mandan, North Dakota - probably in 1953.

Intermediate wheatgrass - Northrup-King Company, #D6-1, grown in Washington.

Native slender wheatgrass - harvested at an elevation of 9,400 feet in Ephraim Canyon in September 1957.

Tall oatgrass - grown in Virginia in 1955, Snelson Seed Company, (No. 633) Atlanta, Georgia.

Native mountain brome - harvested at an elevation of 9,000 feet in Ephraim Canyon in September 1957.

Manchar smooth brome - grown in Oregon in 1952, certified, No. 103019.
Red fescue - grown in Oregon, certified, Northrup-King, #6178.

Sacks containing 100 seeds of a single species were planted at a depth of 2 centimeters (3/4-inch) at each location. Sacks were placed in groups with seven sacks containing the seven species in each sampling unit or replication. Due to the very rapid deterioration of these cotton sacks all sacks were placed on fiberglass screen. Planting procedures were as follows: Two centimeters of soil was first removed from the planting area, a piece of fiberglass screen approximately 5 inches wide and 36 inches long was laid on the exposed soil. The seven sacks were placed at random along the fiberglass screen and the original soil cover was placed over the sacks and screen (fig. 18). Soil was then firmed over the sacks.

At the sagebrush and mountain brush sites the sampling groups were placed between two rows of marker stakes as shown in figures 19 and 20, so that the seeds could be easily located. This arrangement was not suitable at the aspen-fir site since a heavy snow cover is normal during the winter months. To make location of seeds possible when a deep snow cover was on the ground at the aspen-fir site long stakes (8 feet) were placed in line at intervals of 10 feet. A 6 x 6 foot area was located with its center 10 feet north of each location stake. These 6 x 6 foot areas were then cleared of all vegetation. Two units or replications of 7 sacks on fiberglass screens were then planted together within each of the 6 x 6 cleared areas. A total of 26 sampling units or replications were planted at each site. This study was established to provide 13

Figure 18 .--Sacks containing seed were placed on fiberglass screen and the original soil cover was placed over the sacks and screen.

Figure 19 .—This photo shows sacks containing seeds of seven species placed on fiberglass screen. Pertinent climatic data is taken at the weather station shown in the background.

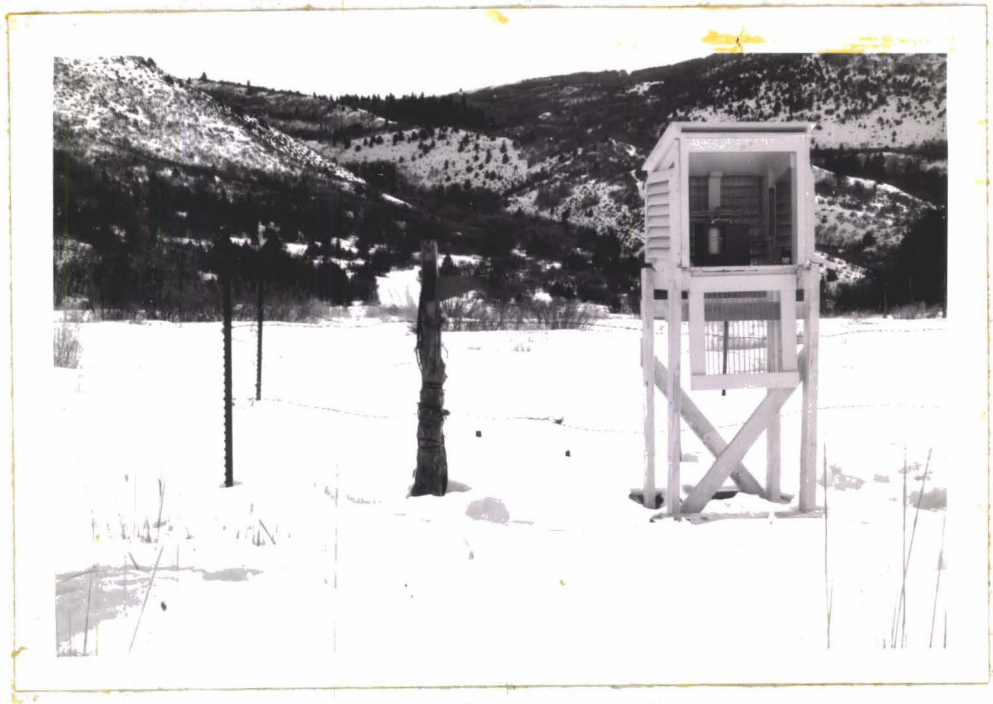


Figure 20 .—This photo shows the climatic station established at the mountain brush site.

separate sampling dates with 2 replications of 7 sacks to be removed from each site on each sampling date. All sampling is to be at random except that the two sampling units placed together in the aspen-fir type will both be removed at the same time.

Seed was placed in the ground at the aspen-fir site on October 31, 1957. Approximately 2 inches of snow was removed from this area to plant the seed and 4 inches of new snow fell during the night of October 31, and the aspen-fir site had been under a continual snow cover since that date. Seed was placed under the soil at the sagebrush and mountain brush site on November 1, 1957. The sagebrush site has been under snow cover most of the time but the snow has been shallow.

Climatic stations were set up at each site prior to planting or plantings were made near established climatic stations operated by the Forest Service. At each site equipment was present to measure continuous air temperature at 4 feet above the soil, separate maximum and minimum temperatures on a weekly basis, continuous soil temperature at 2 centimeters below the soil surface, intermittent electrical measure of soil temperature and soil moisture at the soil surface, and at depths of (2 centimeters) 3/4, 6, 12, 24, and 48 inches. In addition, temperature and moisture units were placed at 3/4-inch and 6 inches above the soil surface at the aspen-fir site. Continuous air and soil temperatures were usually taken with 2-pen thermographs. Soil moisture and soil temperature readings were taken on Monday of each week with Coleman blocks and a Coleman meter. All climatic stations were visited on Monday of each week and supplemental information such as the depth of snow, presence of ice and similar information was recorded.

All areas were sampled on November 17, 16 or 17 days after planting, and at intervals of 2 or 3 weeks since that time. The tenth sampling date at all three sites was removed on April 7, 1958. On this date the snow pack at the aspen-fir was 74 inches deep. This study will be continued until the winter snow pack melts from the aspen-fir site. Based on snowmelt in previous years and the present snow pack the ground will probably be snow free about the first week in June. On April 7, 1958 the mountain brush site had a snow cover of 2 inches and the soil was frozen to a depth of 1/2-inch. On this date the sagebrush site was free of snow, green growth on established crested wheatgrass plants was about 3 inches high, winter moisture had gone to a depth of 4 feet and the soil below 6 inches had started to warm.

Seed sacks have been removed from all areas on the same day so that seed behavior on the different sites could be compared by dates. In general the sagebrush site has been relatively free of snow and the top 1 to 3 inches of soil has frozen and thawed intermittently. At the mountain brush site the soil has been frozen from a depth of 1 to 6 inches for a large portion of the winter, although a shallow snow cover has been on the ground most of the time. A continual snow cover has been on the aspen-fir site since the day the seeds were placed under the soil. Snow depth has been over 24 inches since December 15, 1957 and was 74 inches on April 7, 1958. A thin crust 1/8 to 1/4 inch thick has been observed just above the soil on several sampling dates, but the soil has not been frozen.

As mentioned above sacks containing seed have been removed every 2 or 3 weeks beginning on November 17, 1957. At the aspen-fir site it

has been necessary to dig through a relatively deep snow cover to reach the seed. When the soil has been frozen as has occurred several times at the mountain brush site and twice at the sagebrush site it has been necessary to chop through the ice and frozen soil around the fiberglass screens. The fiberglass screens were then easily separated from the frozen soil below without damage to the sacks and the remaining soil was carefully removed. Some damage occurred to roots and shoots protruding through the sacks but this could not be avoided. The fiberglass screens placed below the sacks have greatly facilitated the removal of the samples since all sacks can easily be located. At the aspen-fir site the screens have been especially valuable since the cotton sacks have been attacked by fungi, bacteria, or other organisms and literally fell to pieces.

Care has been taken in removing all sacks. The sacks have been carefully examined for protrusion of roots and shoots. All samples are labeled and placed in small plastic bags where they are held at near freezing temperatures until they can be carefully examined in the laboratory. The bags are open in the laboratory and observations are made on number of seeds that have germinated. Measurements are made on maximum and average length of shoots and roots and observations on appearance and condition of seeds are made. All seeds or seedlings are then placed on moist silica sand with self-sealing lids and placed in a germinator at alternative temperatures of 28°C. for the first 8 hours in each day and at 20°C. for the remaining 16 hours in each day. Daily observations were made for the first 2 days and periodic counts are made on all

additional germination. After 2 days and on subsequent observations, all seeds that developed normal roots and shoots were removed and discarded. All samples were held at favorable germinating temperatures for 6 weeks when final counts were made and the samples were discarded. It is believed that these observations have given information on damage to seeds, seedlings, and seed dormancy which has been induced.

Since this study will not be completed until June of this year, data on hand will not be included in the report. All data on seed, seedling behavior, and information on climatic conditions will be released in a subsequent report after the study is completed or in the 1958 Annual Report.

A. C. Hull reports that he is also conducting a study (spring of 1958) on germination of intermediate wheatgrass under snow at Franklin Basin on the Cache National Forest. His procedures are similar to and based on the studies completed in 1956-1957 (Section III-B-2).

III-C. HARSH SITES AT HIGH ELEVATION

III-C-1. Free water in the snow and soil

a. High water marks and other signs observed in the spring of 1956 indicated that water reached in excess of 3 and 5 inches in the early spring on two separate study areas, that would normally have drained freely. This indicated that flooding probably occurred under the snow during rapid spring snowmelt.

To test this theory, "free water traps" were made by placing a small can, bottom side up, over the top of an open 1/2 quart beverage can, as a loose lid. Small air holes were made on the side of this lid, allowing air to escape when water entered. These cans were fastened together with wire so that bottom of the inverted can was at least 1/2 inch above the top of the beverage can. The larger diameter of the top can gave a minimum of 1/4 inch of space between the sides of the top can and the beverage can. Cans were then buried in the soil so that the lip of the beverage can was 1, 2, or 3 inches above the soil surface (fig. 21). These traps could only be filled by flowing water.

In the fall of 1956 "free water traps" were placed at the locations numbered 1 through 5, shown in Section IIIC-2, to determine if free water occurred in the snow pack during the spring of 1957. When the cans were checked in the spring of 1957, all cans placed at levels of 1, 2, or 3 inches on shallow, heavy textured soils with slopes less than 5 percent were filled with water. Some cans placed with the opening at 1 inch above a heavy textured soil on slopes of approximately 15

Figure 21 .--"Free water traps" were buried with the lip of the can 1, 2 or 3 inches above the soil surface (B57-76).

Figure 22 .--Snow depth on south and southwest exposures are often quite shallow in comparison to level areas and north exposures (B57-40).

percent were also filled with water but cans with the opening 3 inches above the soil were not filled. The 2-inch height was not used on this area. All of these areas drain rapidly when the soil is snow free. Six cans, placed with the lip 1-inch above the soil surface on a slope leading to a natural drainage at Manti Ridge, on soil of moderate texture and 2 to 6 feet deep, were all filled with water. The 2 and 3-inch heights were not used at this location. All cans placed on rocky coarse textured soils with the lip 1, 2, or 3 inches above the soil surface were empty in the spring of 1957. However, all of the areas tested were on south or southwest slopes with a slope of 5 to 15 percent, with rocky coarse textured soils. Observations made in the winter of 1957-1958 indicate that these south and southwest slopes do not have a deep snow cover during the winter months, probably due to prevailing winds and exposure (fig. 22).

Active flooding on Philadelphia Flat was observed on several dates in the late spring of 1957 (figs. 23 and 24) and some flooding was observed in the fall of 1957 after heavy snow melting following storms. Pronounced flooding under snow was also observed on June 5, 1957 on a trip to Franklin Basin on the Cache National Forest with Orval Winkler and A. C. Hull. Evidence of flooding during the spring of 1957 was also observed at several other locations on the Cache and Bridger National Forests in the summer of 1957.

Pocket gopher activity may have a pronounced influence on the water level in snow, especially on slopes. Soil casts 1½ and 2½ inches in diameter placed along the slopes by the gophers may act as small dams

Figures 23 and 24 .—Active flooding on Philadelphia Flat was observed in the spring of 1957. Dogtooth violets and Spring Beauties can be seen protruding through the snow (B57-49 and B57-50).

to back up the water. On the other hand, gopher holes often provide rapid drainage for large volumes of water. Drainage through gopher holes may be in channels under the soil surface or under the snow at the soil surface.

"Free water traps" installed in the fall of 1956 and observations demonstrated that flooding under snow occurred under the conditions existing in the spring of 1957. However, "free water traps" do not provide any information on duration or frequency of flooding and a cooperative study to measure these factors in the spring of 1958 was initiated.

b. Additional "free water traps" were placed at selected areas to obtain additional information on free water in the snow in the spring of 1958. Traps were placed at the following locations in the fall of 1957.

1. Philadelphia Flat.
   A. Every 50 feet from level land up a slope for a distance of 300 feet. (Maximum slope of about 14 percent).
   B. Study areas comparing seed germination and seedling growth in snow, sand and soil.
   C. Near uniform study.
2. Head of Ephraim Canyon above the Alpine cabin (listed as Alpine in pot fertility study).
3. Above John August Lake.
4. Monument on Skyline Drive south of John August Lake.
5. Near uniform study area at the Summit Enclosure.

Heavy rain and snow storms during the period October 1 to October 23 resulted in puddling and soil saturation. Infiltration rate appeared to be very low. Snow falling on the areas acted as small dams. This retarded the movement of water into the natural drainage and retarded the movement of water down the drainages. Water up to 3 inches deep was observed in low areas and in the drainages, but was not deep enough to fill the 1-inch "free water trap." A heavy snow storm on October 23 laid down a permanent winter snow cover. When Philadelphia Flat was visited on October 29 the average snow depth was 14 inches with some drifts over 24 inches deep. On this date the soil was not frozen and appeared to be at or near saturation and all water traps were empty.

According to a Work and Report Schedule for Study 57-1, A. C. Hull is apparently testing my flooding under snow theory at Franklin Basin. His report states "install 36 trap cans to determine flooding at snow melt" in October 1957.

c. A cooperative study between the Watershed Management Research Division of the Intermountain Forest and Range Experiment Station, Forest Service and the Ephraim Project was activated to develop equipment that will record the occurrence, frequency and duration of free water in the soil and at selected points in the snow during spring snowmelt. Since the "free water traps" now in use only determine the occurrence of free water but will not show duration or frequency of this condition, suitable equipment is needed. This information is needed because it is known that flooding may have an adverse effect on germinating seeds, seedlings and even established plants. Snow hydrologists are interested because the presence of free water is vital to the study of snowmelt.

Two replications of snow and soil units were made. Units were laboratory tested and installed on Philadelphia Flat on February 28, 1958 where water tables in the snow were known to have occurred in the spring of 1957. This equipment will be placed in operation about April 1 and continuous operation will be maintained during the active snowmelt period in the spring of 1958.

Snow depth averaged 74 inches on this date. A trench about 35 feet long was made in the snow. One replication of soil and snow units was placed at each end of the trench. Wires to the electronic units were laid along the bottom of the snow trench for approximately 17 feet to a mid-point in the trench and then brought to the top of the snow. In each replication a soil unit was placed 3/4-inch (2 cm.) below the soil surface and 4 units (fig. 25) were placed in the snow at 1/2, 1, 2, and 4 inches above the soil surface. Thus a total of 10 units were wired to the electronic unit which in turn was connected to a 10-pen Esterline-Angus recorder. In addition, "free water traps" were placed at 1-inch and 3-inches above the soil near each stack of units. Snow was then shoveled back into the trench.

There was some sign of recent gopher activity on the west end of the trench although this area was thoroughly trapped just prior to snowfall in September and October. Many ice crusts were found in the snow and a slight ice crust was found just above the soil surface. The soil was moist but on an area 50 feet to the east the soil appeared to be at near the moisture saturation point (sticky and glistened).

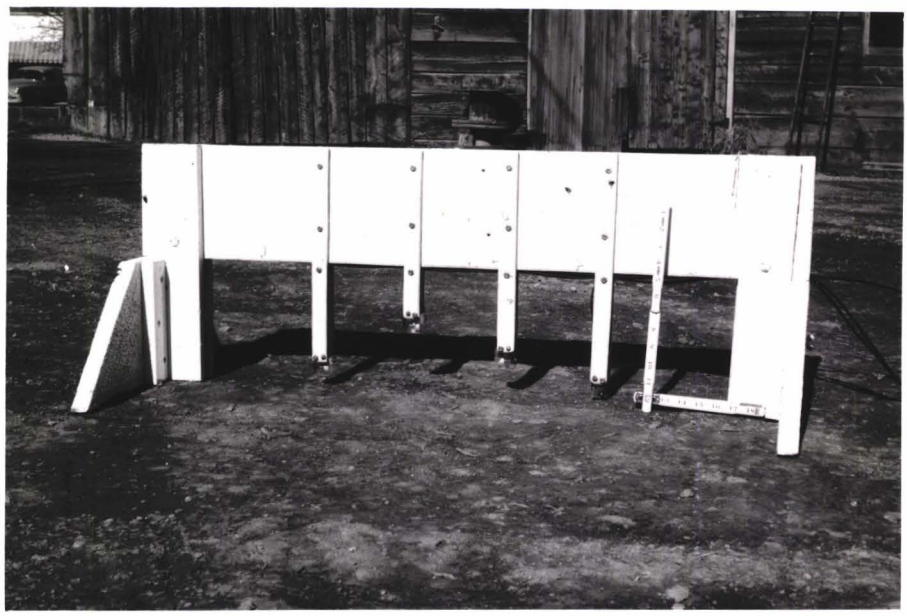


Figure 25 .—These units were placed in the snow at ½, 1, 2, and 4 inches above the soil surface to record occurrance, frequency and duration of free water (B58-).

Upon completion of the study, a paper will be prepared describing the instrument and presenting the information obtained during the field test. The significance of the findings as they affect plant cover at the test site will be discussed. Drawings and photographs of the snow and soil units, schematic diagrams of the circuits used, and a discussion of the merits and possible modification of the instrument will also be discussed. Results will be published under joint authorship with R. O. Meeuwig as senior author.

III-C-2. Row plantings in the fall of 1956

Row plantings were made on six areas with various slopes and soil types so that a comparison of seedling stands on these areas could be made in the spring of 1957. Furrows 20 to 100 feet long and 4 inches deep were made with a hand cultivator. Seed of smooth brome was planted at a depth of 3/4 inches in the bottom of each furrow with a Planet Jr. Seeding rate with the Planet Jr. was set for 10 pounds per acre when rows were spaced 1 foot apart. The locations of the study areas, supplemental information and seedling stands in the spring of 1957 are shown below. "Free water traps" were also placed at areas listed below, except for number (6).

1a. Philadelphia Flat. Elevation 9,950 feet. Sixteen furrows (8 on mulched plots and 8 on natural plots) were established on the west end of abandoned study which was relatively free of lupine. Poor seedling stands in the spring of 1957 (0.3 plants per linear foot of row). Some plants were 1 to 2½ inches tall the day the winter snow pack melted (June 27) exposing the soil (fig. 26). Cold weather type of albinism was found on many of these seedlings. Some of these plants were distinct albinos but others contained chlorophyll in the lower portion of the shoot. All distinct albino seedlings perished but some seedlings with chlorophyll in the lower portion of the shoot survived. All "free water traps" on this area were filled in the spring of 1957.

1b. Philadelphia Flat. Elevation 9,950 feet. Located on a 15 percent slope, 300 yards south of number (a) above. Four furrows were established with the contour of the slope. Fair seedling stands in the

Figure 26 .—Some seedlings of smooth brome were 1-2½ inches tall when the winter snowpack melted on June 28, 1957. This smooth brome seedling exhibited a cold weather type of albinism (B57-53).

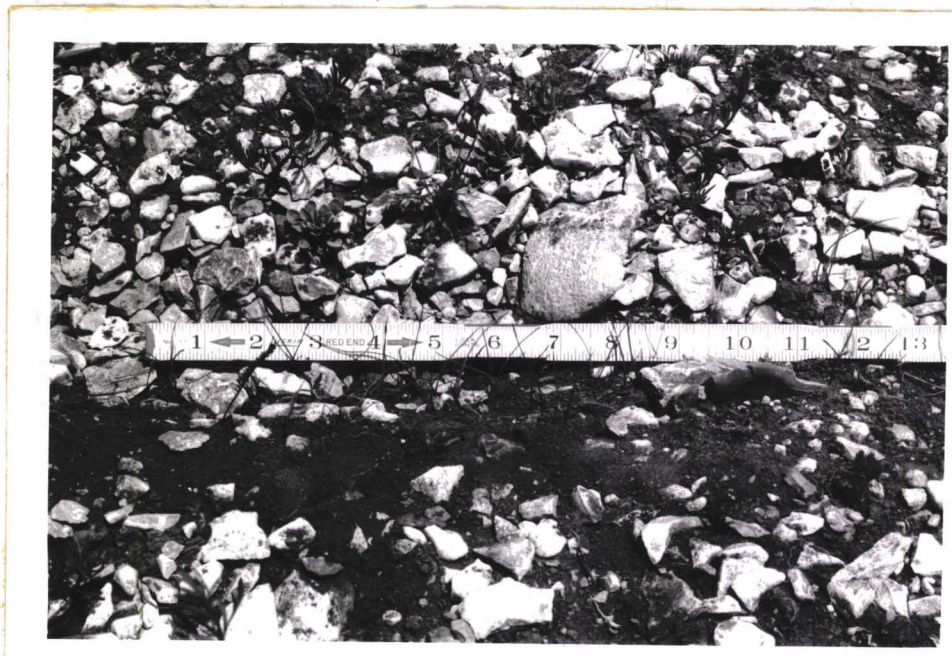


Figure 27 .—This rocky coarse textured soil on a southwest slope supported an excellent stand of seedlings in the spring of 1957.

spring of 1957 (0.9 plants per linear foot of row). Some cold weather albinism observed. Water traps at 1 inch above the soil were filled with water but cans at 3 inches above the soil were not filled.

2. Head of Ephraim Canyon. Elevation 10,200 feet. This area adjoins the 1955 planting which produced fair to good seedling stands in the spring of 1956. Eight furrows were made south of the 1955 planting. Excellent seedling stands in the spring of 1957 (9.8 seedlings per linear foot of row) (fig. 27). Water traps were not filled at this location.

3. Bear Creek. Elevation 10,100 feet. Established on lower portion of a livestock exclosure near the Bear Creek road and east of old log and block enclosure. Good seedling stands were produced on this or adjacent areas from fall plantings in 1948 and 1949 and spring plantings in 1949 and 1950. Excellent seedling stands (7.4 plants per linear foot of row) in the spring of 1957. Water traps were not filled with water.

4. Manti Ridge. Elevation 9,000 feet. Located within a large administrative Forest Service planting. Good stands were produced on the rocky ridges but poor stands were produced on the deep soil in the swale from the administrative planting in the fall of 1949. Three furrows 100 feet long extend from bottom of swale onto slope of approximately 8 percent and on rocky ridge. Good seedling stands were present on the rocky ridges (7.1 plants per linear foot of row) but poor stands were present on the deep soil in the swales in the spring of 1957. Water traps on the rocky ridges were empty but those in the swale were filled.

5. Rock Monument on Skyline Drive near John August Lake. Elevation 10,300 feet. Four rows approximately 35 feet long were established on the contour. Fair to poor seedling stands (0.6 plants per linear foot of row) in the spring of 1957. Water traps at 1 inch depth were filled.

6. Buck Ridge near old Sampson plots. Elevation 9,800 feet. Six rows were established. Rows are in pairs with two near rocky ridgetop, two on rocky ridge face, and two on level terrace. Good seedling stands (5.5 per linear foot of row) were present on rocky ridge and fair stands were present (1.3 and 2.2 plants per linear foot of row) on the rocky face and on the level terrace. Water traps were not used at this location but signs of puddling and crusting were observed on the level terrace.

III-C-3. Methods of planting study on Philadelphia Flat in 1956-1957

A methods study was made on Philadelphia Flat to determine the relative effects of furrows compared to no furrows, sawdust mulch compared to no mulch, and nitrogen fertilizer compared to no fertilizer. A total of eight different treatments were used. Each treatment was replicated six times. Furrows 4 inches deep were spaced 2 feet apart in the furrowed plots. All plots were planted with Manchar smooth brome at a depth of 3/4-inch and at a rate of 10 pounds per acre. A Planet Jr. was used for planting and rows were made 1 foot apart. In the furrowed plots one row was planted on the interspace between the furrows. Sawdust was hand broadcast at a rate of 2 cubic feet per 100 square feet of area. Ammonium nitrate was broadcast over the area at a rate of 100 pounds per acre.

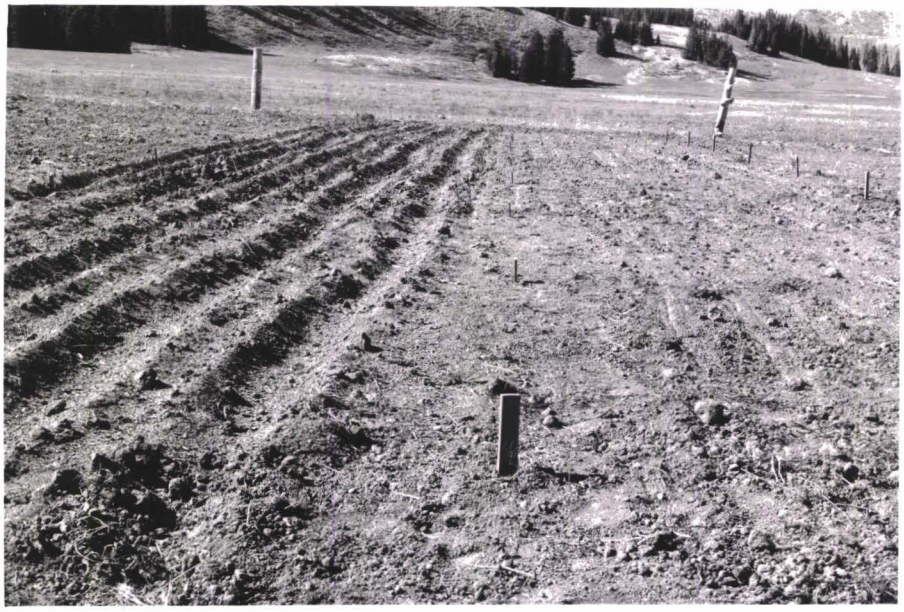
Previous plantings on this area have failed to produce good stands. This study is similar to a study established by W. J. McGinnies on an adjacent area in the fall of 1955 (see page 141 of the 1956 Annual Report for this location). The study established by W. J. McGinnies as well as other previous plantings on this area failed to produce good stands. Future work with planting methods and fertilizers will be part of the uniform study described in Section III-D-1.

This area was free of snow on June 27, 1957 and many gopher casts were on the area. Definite signs of flooding were visible on this date. All trap cans including two placed ith the lip 3 inches above the ground were filled with water. High water marks from 4 to 7 inches above the soil level could be seen on plot stakes. Furrows, ridges and

gopher casts showed signs of flooding. Figure 28 shows the plot area on October 16, 1956 and figure 29 shows the same area on June 28, 1957, one day after the winter snow pack had melted from the area. Figure 30 shows the natural vegetation on the adjoining area on July 13, 1957.

Many of the smooth brome seedlings were from 1 to 1½ inches high when the snow melted. Cold weather albinism was common on these seedlings. As mentioned on the adjacent row plantings distinct albinos perished but some of the plants with chlorophyll in the lower portion of the stem survived. Seedling counts made on July 13 showed some advantage for the furrowed plots and for the mulched plots. Most of the seedlings on furrowed plots were not in the furrows but on the interspace between the furrows. Sawdust mulch showed some advantage over the nitrogen and check plots. In general, these results were erratic and inconclusive due to flooding, frost damage, albinism, crusting of soil, gophers, aeration, grasshoppers, other insects and pathogens. Average number of plants for each treatment on July 13, 1957 are shown below.

	Plants per linear foot of row	
	No. furrows	Furrows
Control	0.47	0.71
Nitrogen	0.49	0.81
Sawdust	0.77	0.87
Sawdust and nitrogen	0.57	0.86



Figures 28 and 29 .—Compare the upper photo taken on October 16, 1956 with the lower photo taken on June 28, 1957, the day after the winter snow pack melted. Note that furrows, ridges, and gopher casts show effects of flooding (B56-137 and B57-58).

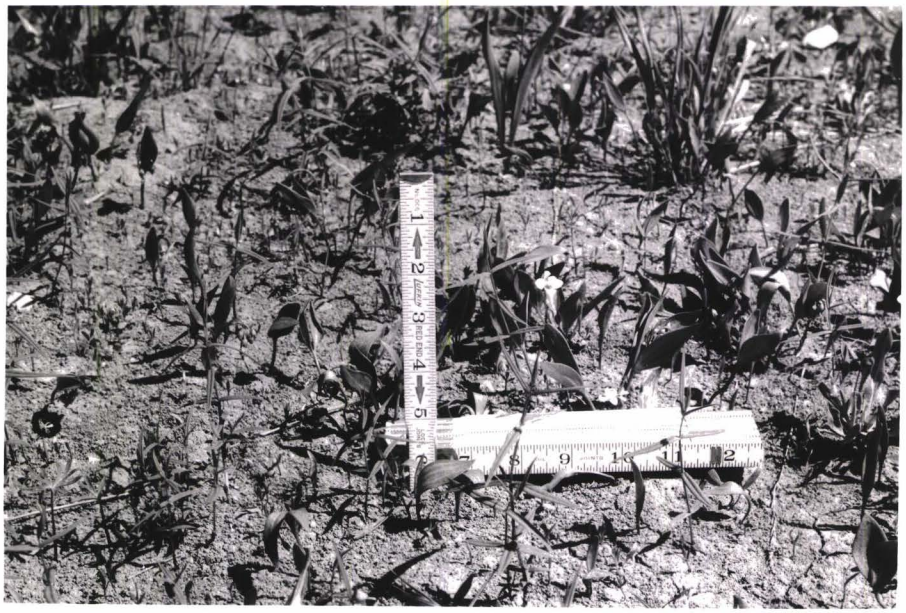


Figure 30 .—The natural vegetation near the methods of planting study on Philadelphia Flat was dominated by spring beauties, violets, annual weeds and occasional plants of mountain brome.

III-C-4. Pot fertility test on soils from harsh sites and high elevations in central Utah

In the past, large scale range revegetation has been largely confined to the better sites. However, as the better sites have been seeded work has moved into the harsh sites where soil, available moisture, and environmental conditions may be limiting. Field planting on these areas in central Utah have usually resulted in good seedling stands, but on some areas repeated failures have occurred. On some areas where good seedling stands have been produced the seedlings lacked vigor and made little growth. Since temperature, light, precipitation and many other environmental conditions appear to be similar to adjacent areas now supporting a good native or artificially revegetated cover, tests to determine deficiencies and limitation of the soil may be desirable.

Since the pot fertility study has been used for several types of tests the advantages and disadvantages of several methods will be discussed. In general, pot tests can be divided into two major types of studies. One is where major emphasis is placed on the response of plants when grown in selected mediums such as soil. The other is where major emphasis is on the soil and selected plants are used to indicate soil characteristics. A combination of these tests can be used under certain conditions but all of these studies have definite limitations which should not be overlooked.

In selection of the methods to be used the following questions may be pertinent to the value of the results: Are the tests made to evaluate the ability of the soil to support vegetation (are macronutrients and micronutrients present in quantities at or above the

minimum requirement for growth of most plants--are toxic conditions present in the soil)? Are the tests made to evaluate the growth of a single species on a specific soil under the conditions of the study? Will the study be made with soil where a fair knowledge of the soils capabilities and adapted species are known. Will it be on harsh sites where little is known about the soil, its limitation, productivity or adapted species? If on harsh sites where some factor is known to limit plant establishment or plant growth, will it be to determine the limiting factors? Will the study be made in a greenhouse, a coldframe, or in a controlled climatic cabinet where conditions are similar to the natural site? Will the study be of short duration or will it be carried on for a relatively long period of time. The objectives of the study will usually determine what plants are grown, what soil or nutrient medium is used, the quantity of soil per unit, source of water to be used, conditions under which these tests are made and duration of the study.

Size of soil samples in relation to plant demands for macronutrients, micronutrients and moisture available to the plants may have considerable bearing on results obtained. Where a test is primarily to evaluate a soil, relatively small soil samples in conjunction with rapid growing test plants should provide more information on a soils ability to provide macronutrients and micronutrients than large soil samples. Small soil units may be especially desirable when tests are conducted for a relatively short period. On the other hand small soil samples may not hold sufficient moisture to sustain planted species,

especially if plants are grown where humidity is low, temperatures high and winds of moderate to high velocities. Where plant behavior, including root and top growth, is of major importance it may be desirable to grow plants in larger soil volumes comparable to conditions existing under natural conditions.

When the response of a particular plant to a specific soil is desired, it seems wise to use this plant in all tests. However, the response of other species or even different strains of the same species to a specific soil can not be predicted unless the behavior of the test plant to various conditions is known. In general, most of the common perennial range grasses are relatively tolerant of low fertility and may not show macronutrients or micronutrients to be in short supply. Also, where test plants are grown from seed the common range grasses are relatively slow growing, but this can be overcome by using established plants or clones. This method may not yield reliable information on tests for some trace elements since a healthy test plant containing all elements needed for plant growth may be able to make additional growth although the micronutrient or trace element is in short supply.

Where a test of soil productivity, deficiencies, excesses or limitations is desired it seems wise to use sensitive indicator plants. Where specific conditions are tested, plants sensitive to these conditions can be used. For example, lettuce is known to be sensitive to soluble aluminum. Where a rapid evaluation of soil potential is desired, rapid growing, sensitive annuals may provide more reliable information than many of the slower growing perennial grass species. In general, it is

believed that relative macronutrient and micronutrient levels as indi- by these pot tests will be correct, providing soil pH is not greatly altered.

When soils from harsh sites and problem areas, especially at high elevations, are brought in from the field the environment may be drastically altered. Thus, response and behavior of test plants may be strongly affected by local environment.

Total environment of a harsh site cannot be evaluated from pot studies conducted in a greenhouse or coldframe for several reasons. Studies with soils from harsh sites at high elevation are usually made in greenhouses or in coldframes at near optimum soil moisture and at relatively favorable temperatures. Soil samples are usually confined to the surface 6-8 inches and may not give an indication of conditions in the subsoil. Soil is passed through screens removing rocks and larger roots and other similar matter. Soil structure, moisture holding capacity, aeration and other factors may be seriously altered. After soil productivity, deficiencies, excesses and limitations have been determined, a partial evaluation of existing environmental factors on the study site may also be possible, based on this information and plant behavior under natural conditions.

When environmental conditions on the site are strongly dissimilar to conditions used in the pot studies it does not seem wise to make specific recommendations on soil productivity based on these results. Nor does it seem wise to draw specific conclusions on the behavior of a specific plant growing on the native area based on these results. On the other hand, if we make general recommendations, realizing some of the limitations, we should be on safer ground.

Pot fertility studies were used in the summer of 1956 at Reno, Nevada and again in the summer of 1957 at Ephraim, Utah. The objectives of these studies were to provide rapid evaluation of productivity, excesses, deficiencies and limitations of the soils. The study conducted at Reno in 1956 is covered in the 1956 Annual Report. The study conducted at Ephraim in the summer of 1957 is discussed in the following sections. The methods used were selected to provide heavy demands on a small quantity of soil with fast growing, sensitive plants.

Tests were made on six soils, obtained from selected areas near the Great Basin Research Center. These soils are all from sedementary material and are primarily derived from limestone. Two soils which produce high yielding stands under natural conditions were included. One is from an old grass nursery in the mountain brush type at an elevation of 7,200 feet and the other is from a large scale planting at an elevation of about 9,000 feet. Other soils were from high elevations (9,000 - 10,200) where seedings have been made in two or more years.

Trials were conducted on each soil with both Bonneville barley and Romaine lettuce. These plants were grown in 1/2-gallon cans. Each pot was filled with 1,600 grams of dry soil to which the various chemicals had been added. Tests on the alpine soil were made without replication. All other tests were made with two replications.

Seven different treatments were included in these tests. Tests were as follows: No treatment; micronutrients; nitrogen, phosphates, and potash; nitrogen, phosphates, potash, and micronutrients; nitrogen and phosphates; nitrogen and potash; and phosphates and potash.

Nitrogen was added as ammonium nitrate at a rate of 200 pounds of N per acre. Phosphorus was added as monocalcium phosphate at a rate of 300 pounds of P_2O_5 per acre. Potassium was added as potassium sulfate at a rate of 100 pounds of K_2O per acre. All chemicals and mixtures were dissolved in water and the aqueous solution was thoroughly mixed with the soil. Some of the procedures used were adapted from those described by H. Jenny, J. Vlamis, and W. E. Martin (Greenhouse Assay of Fertility of California Soils, Hilgardia, Volume 20, Number 1).

The eight micronutrients added were mixed together and included as a single test to determine if a response to this mass application of micronutrients would be produced. If a response had been observed an additional test to determine the elements producing the response could be made. The following chemicals and rates per acre were used to supply these micronutrients.

Element	Chemical	Rate of Chemical/Acre
Boron	Sodium borate	20 Pounds
Copper	Copper sulfate	50 Pounds
Iron	Ferrous sulfate	50 Pounds
Magnesium	Magnesium sulfate	50 Pounds
Manganese	Manganous sulfate	50 Pounds
Molybdenum	Ammonium molybdate	1 Pound
Sulfur	Sulfur	100 Pounds
Zinc	Zinc sulfate	50 Pounds

On May 9, 1957, five presoaked barley seeds which had started to sprout or a single lettuce plant were transplanted into the cans. Lettuce plants were 1 month old on this date. Care was taken to wash all soil from the roots of lettuce plant before transplanting into pots. On

May 15 all lettuce plants were living and all weak barley plants were replaced with healthy transplants of the same age. One-half of all cans contained five barley plants and one-half of the cans contained one lettuce plant. All plants were sprayed every 5 to 7 days with malathion mixed as directed for control of mites and aphids. All cans in a replication for each soil were kept together on the table but the position of the cans in each replication and the replications were changed on Monday and Thursday of each week.

Water was added to all cans by weight to bring the moisture content up to approximately "field capacity" for each soil. This was determined for each soil by measuring the amount of water 1,600 grams of air-dry soil would hold when it was allowed to drain freely. Some adjustment of total weight of cans and plants was necessary to adjust for weight of plants in the cans. This was determined by the weight of pot, soil and plant after excess water had drained out through a small hole made in the bottom of the cans. These holes were then sealed. Excess water was caught and this water along with any leached chemicals were used in the following irrigation. Additional tests were made with lettuce plants to determine the weights of soil, can and plant just after the lettuce plant started to wilt. This method was not used on the cans containing barley since the wilting point of barley was very difficult to determine.

On July 9, 1956, 60 days after planting, photographs of all treatments in one replication for each soil were taken. On July 9 and 10 all lettuce and barley plants were cut at the soil surface and placed in paper sacks. Oven dry weights were made on all plants (tables 11 and 12).

Table 11 .—Average height and dry herbage production by Romaine lettuce grown in pots containing soil from 6 locations which received 7 different treatments.

Treatment 3/	1/ Alpine	2/ Lower Bear Creek	2/ Upper Bear Creek	2/ Manti Ridge	2/ Majors Flat	2/ Philadelphia Flat
$N_0P_0K_0$ - Check						
Weight (grams)	1.2	0.1	4.2	9.1	3.9	6.5
Height (inches)	3.0	1.0	4.8	4.5	4.2	4.5
$N_0P_0K_0$ plus micronutrients 4/						
Weight (grams)	3.5	0.5	3.1	9.8	4.3	4.4
Height (inches)	5.5	1.8	4.8	4.8	4.0	4.2
$N_0P_3K_1$ - Phosphates and potash						
Weight (grams)	6.0	1.0	4.8	12.7	3.9	5.5
Height (inches)	5.0	3.2	4.8	6.5	4.2	5.0
$N_2P_0K_1$ - Nitrogen and potash						
Weight (grams)	8.6	0.4	3.6	15.1	7.7	12.8
Height (inches)	6.5	2.0	5.5	6.0	5.2	5.8
$N_2P_3K_0$ - Nitrogen and phosphates						
Weight (grams)	14.1	11.1	12.0	18.6	13.2	13.1
Height (inches)	6.5	5.5	6.0	6.5	5.5	5.5
$N_2P_3K_1$ - Nitrogen, phosphates, and potash						
Weight (grams)	14.4	11.4	14.0	21.2	11.8	17.1
Height (inches)	6.0	6.0	5.8	6.2	5.0	6.0
$N_2P_3K_1$ - Nitrogen, phosphates, and potash plus micronutrients 4/						
Weight (grams)	14.7	10.6	14.5	17.4	10.7	18.0
Height (inches)	7.5	5.8	5.2	7.2	5.0	5.5

1/ No duplication
2/ Average for two replications
3/ The subscript numbers following the nutrient symbols indicate the number of units as follows: N_2 = 200 pounds of nitrogen per acre; P_3 = 300 pounds of P_2O_5 per acre, and K_1 = 100 pounds of K_2O per acre.
4/ Micronutrients added were zinc, iron, copper, magnesium, manganese, sulphur, boron, and molybdenum.

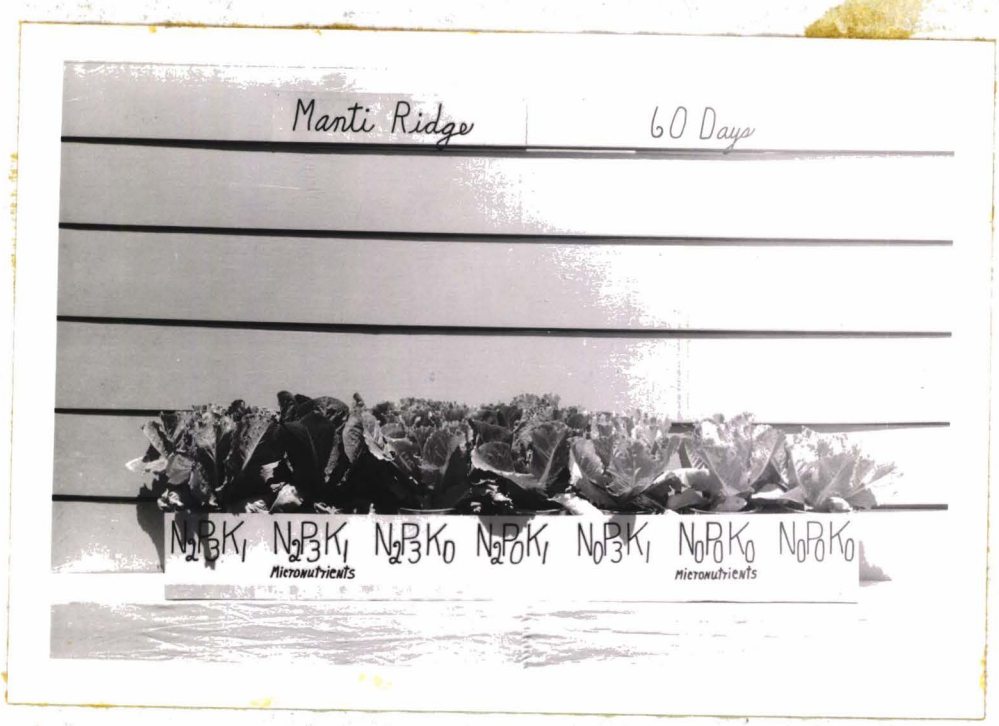
Table 12 .—Average height, average number of seed heads per plot, and dry herbage production by Bonneville barley grown in pots containing soil from 6 locations which received 7 different treatments

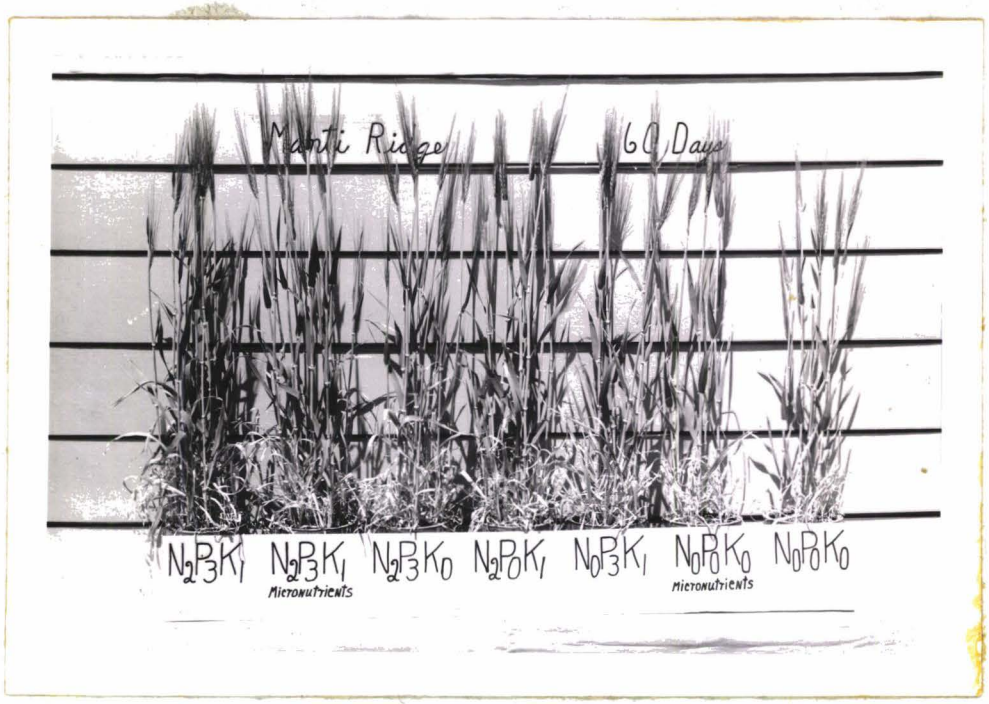
Treatment 3/	1/ Alpine	2/ Lower Bear Creek	2/ Upper Bear Creek	2/ Manti Ridge	2/ Majors Flat	2/ Philadelphia Flat
$N_0P_0K_0$ - Check						
Weight (grams)	4.2	1.2	4.1	6.7	3.1	3.7
Height (inches)	14.0	10.5	16.5	19.5	13.5	14.0
Seed Heads	5.0	5.0	5.0	5.0	5.0	5.0
$N_0P_0K_0$ - plus micronutrients 4/						
Weight (grams)	5.4	1.2	5.2	9.1	4.1	4.6
Height (inches)	17.5	11.0	17.5	20.5	15.5	13.5
Seed Heads	5.0	5.0	5.0	5.5	5.0	5.0
$N_0P_3K_1$ - Phosphates and potash						
Weight (grams)	5.6	1.6	4.4	14.6	3.9	4.4
Height (inches)	16.5	12.0	17.0	20.0	16.0	16.5
Seed Heads	5.0	5.0	5.0	8.5	5.0	5.0
$N_2P_0K_1$ - Nitrogen and potash						
Weight (grams)	10.8	1.3	10.3	16.9	6.1	12.6
Height (inches)	18.5	10.0	20.5	22.2	17.0	19.0
Seed Heads	6.0	0.0	5.5	9.0	5.0	8.5
$N_2P_3K_0$ - Nitrogen and phosphates						
Weight (grams)	11.9	11.2	11.9	16.9	13.0	12.2
Height (inches)	20.5	20.5	22.0	24.0	21.5	21.5
Seed Heads	6.0	7.0	7.5	9.0	7.0	8.0
$N_2P_3K_1$ - Nitrogen, phosphates, and potash						
Weight (grams)	15.3	10.9	12.5	19.9	11.8	12.7
Height (inches)	22.5	21.5	24.0	24.5	22.5	24.0
Seed Heads	7.5	5.0	5.5	11.0	7.0	7.5
$N_2P_3K_1$ - Nitrogen, phosphates, and potash plus micronutrients 4/						
Weight (grams)	13.9	11.5	11.9	18.0	11.4	12.0
Height (inches)	24.5	24.5	24.0	25.0	23.5	24.5
Seed Heads	6.5	6.0	6.5	9.5	6.5	7.0

1/ No duplication
2/ Average for two replications
3/ The subscript numbers following the nutrient symbols indicate the number of units as follows: N_2 = 200 pounds of nitrogen per acre; P_3 = 300 pounds of P_2O_5 per acre, and K_1 = 100 pounds of K_2O per acre.
4/ Micronutrients added were zinc, iron, copper, magnesium, manganese, sulphur, boron, and molybdenum

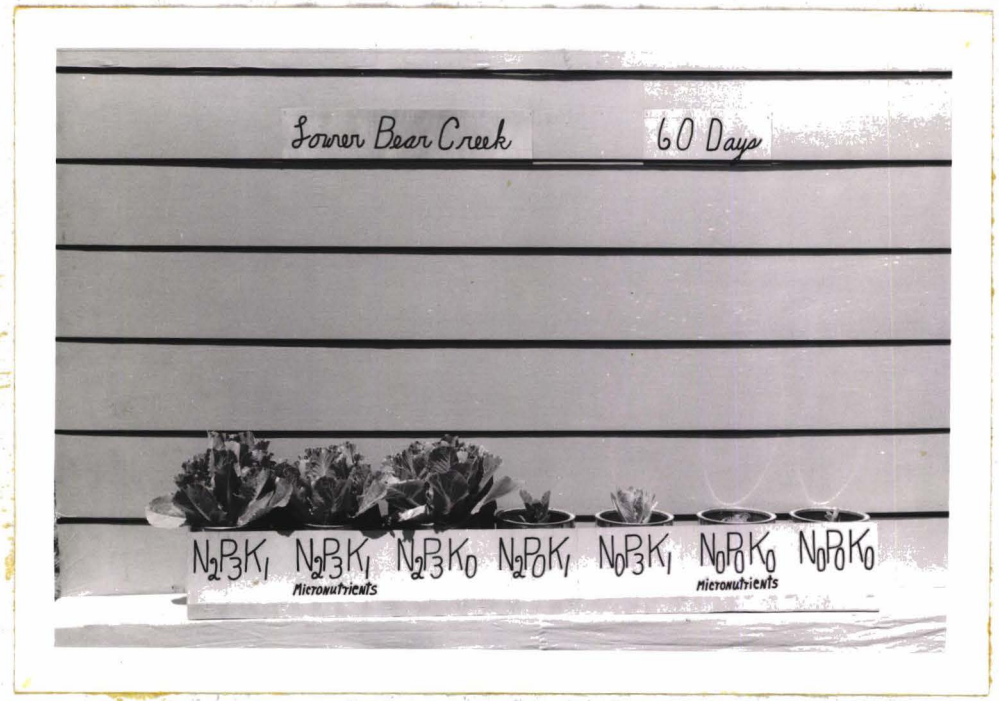
Soils included in this study with the exception of the Majors Flat soil were taken from high elevations where small row plantings of smooth brome were made and where "free water traps" were set out in the fall of 1956. Majors Flat soil was included in this test for comparison with the soils from high elevations since it had been a very productive soil under natural conditions. It is noteworthy that this soil was not a high producing soil in this test, probably due to puddling and baking of the soil in the cans.

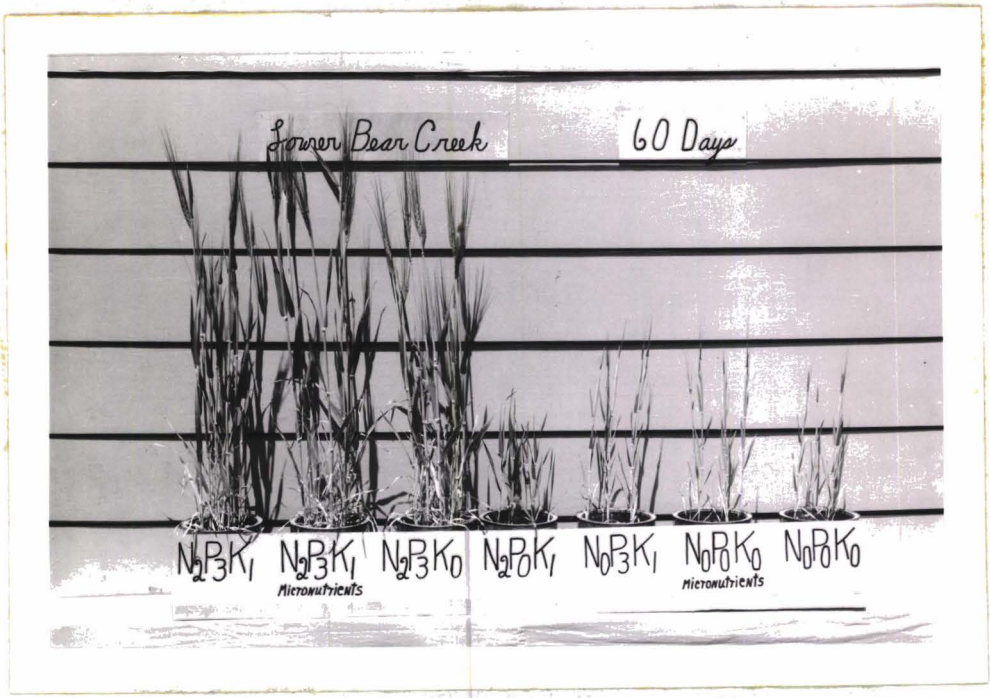
All soils made a good response to the addition of both nitrogen and phosphates. These tests indicate that nitrogen is low on all soil but probably is not a seriously limiting factor in plant establishment except at the Lower Bear Creek site (figs. 31 to 42). Micronutrients and potash did not appear to increase herbage growth of lettuce or barley. The differences between the $N_2P_3K_0$ and $N_2P_0K_1$ treatments on barley was quite pronounced on the Lower Bear Creek and Majors Flat soil. Where lettuce was used as the indicator plant a difference between the $N_2P_3K_0$ and $N_2P_0K_1$ was quite marked on the soils from Alpine, Lower Bear Creek, Upper Bear Creek and Majors Flat.



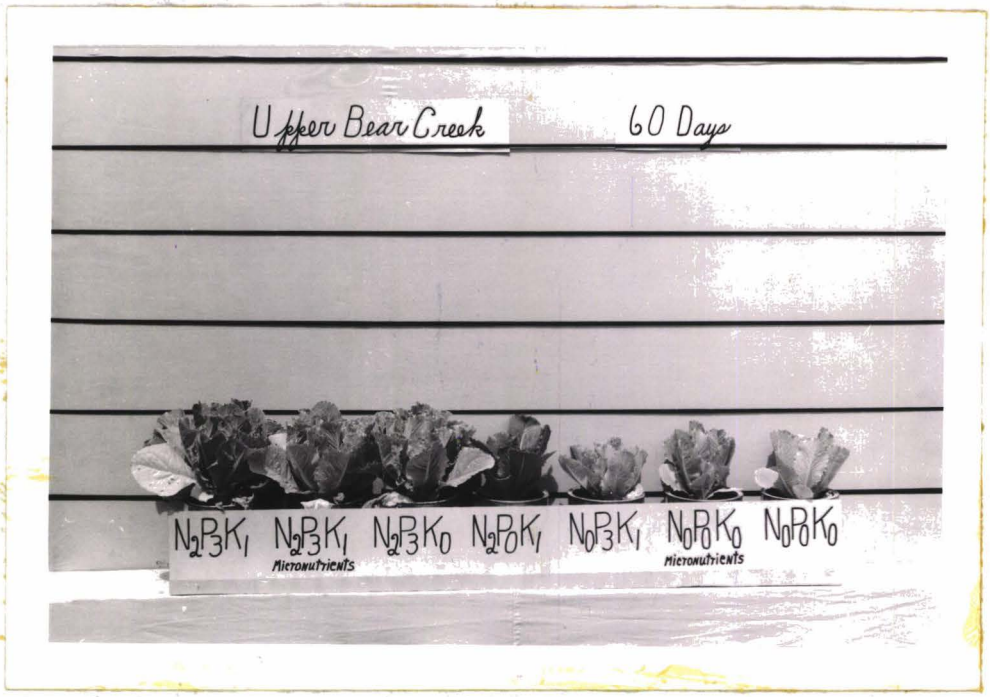


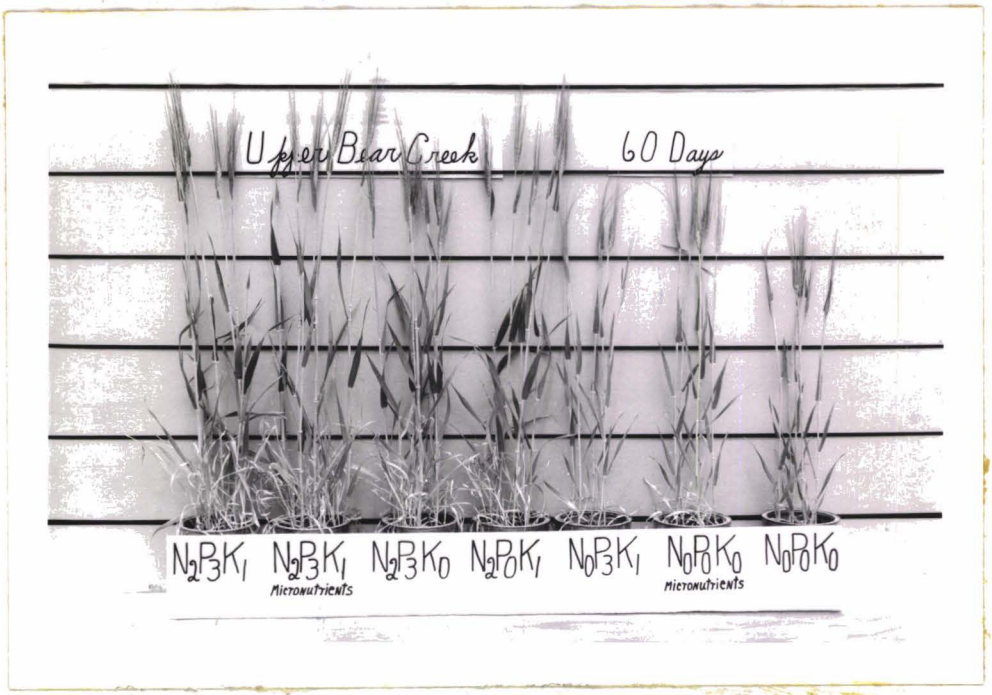
Figures 31 and 32.---Growth of Romaine lettuce and Bonneville barley in 60 days on soil from Manti Ridge which had received various macronutrients and micronutrients (B57-61 and B57-62).



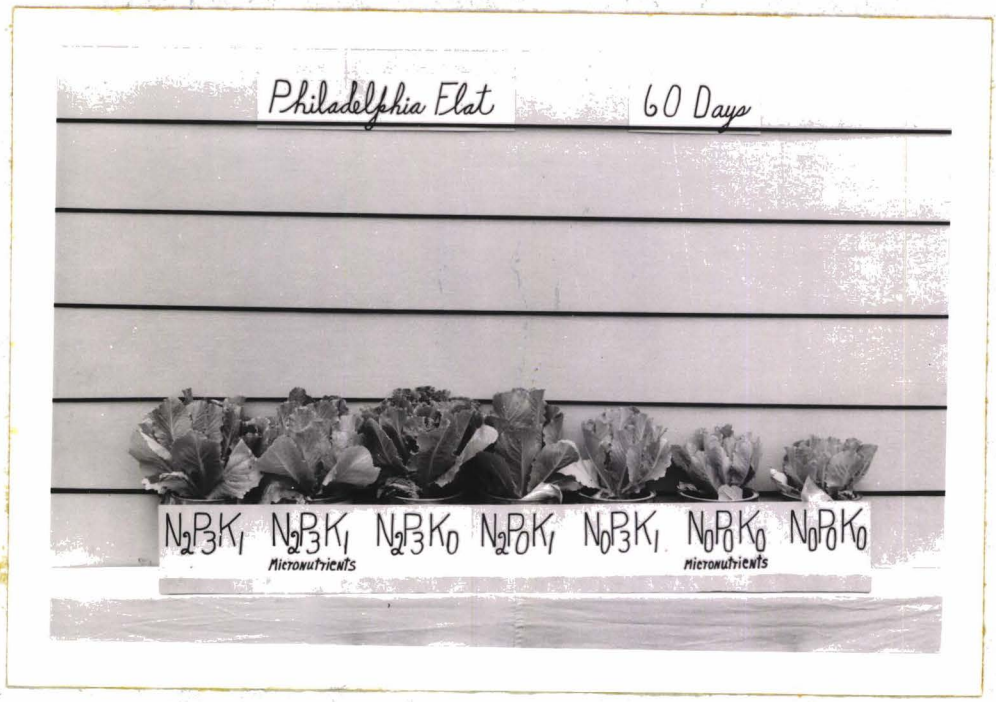


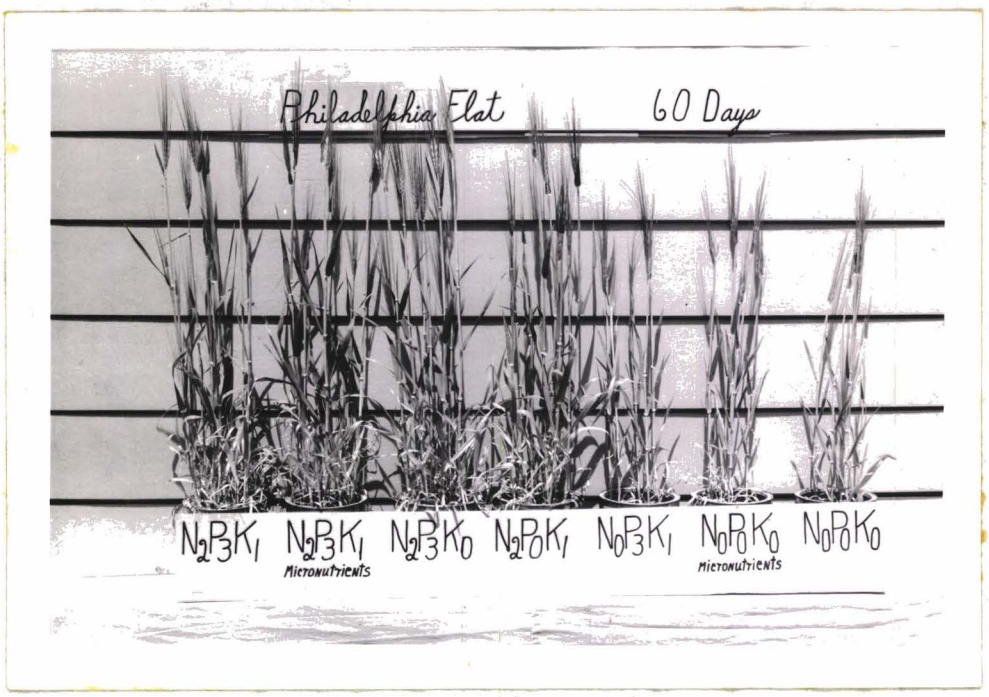
Figures 83 and 84.--Growth of Romaine lettuce and Bonneville barley in 60 days on soil from Lower Bear Creek which had received various macronutrients and micronutrients (B57-63 and B57-64).



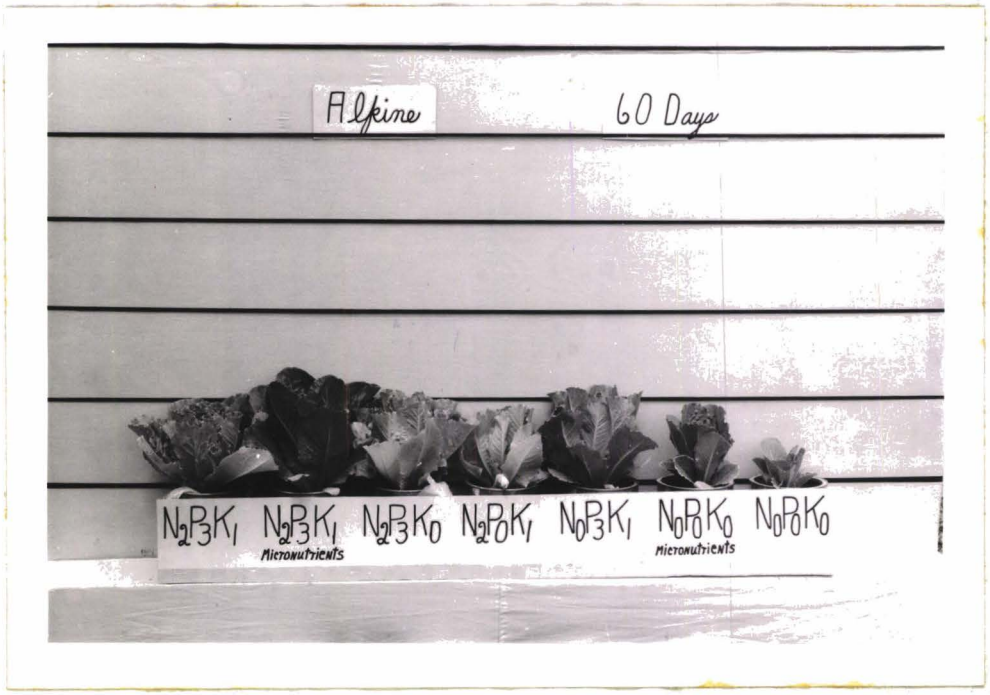


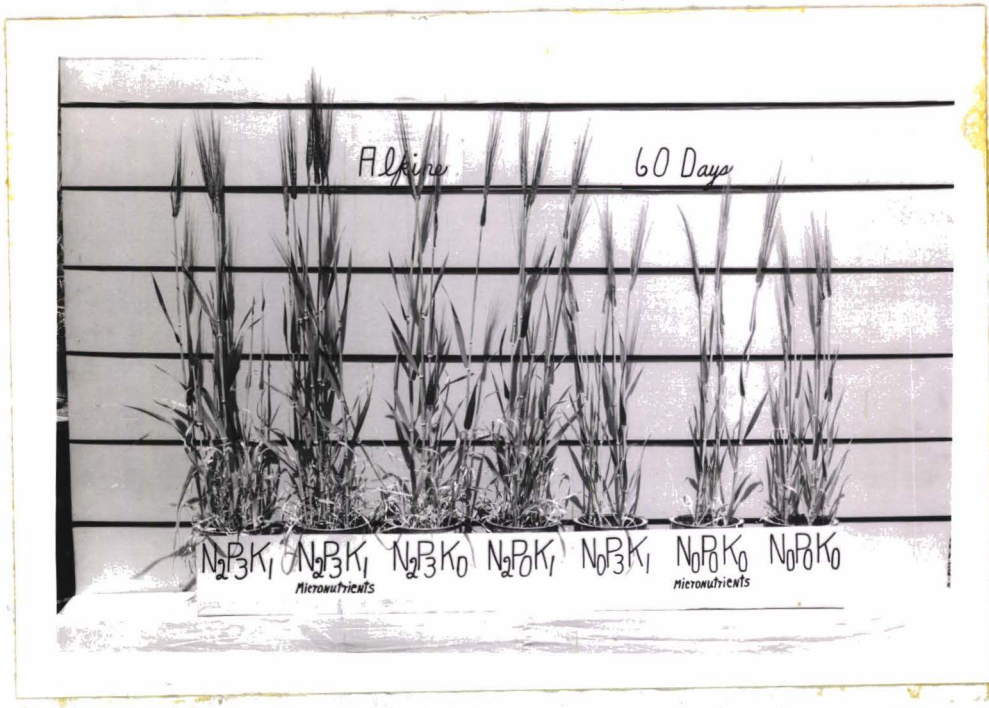
Figures 85and 86 .---Growth of Romaine lettuce and Bonneville barley in 60 days on soil from Upper Bear Creek which had received various macronutrients and micronutrients (B57-68 and B57-67).



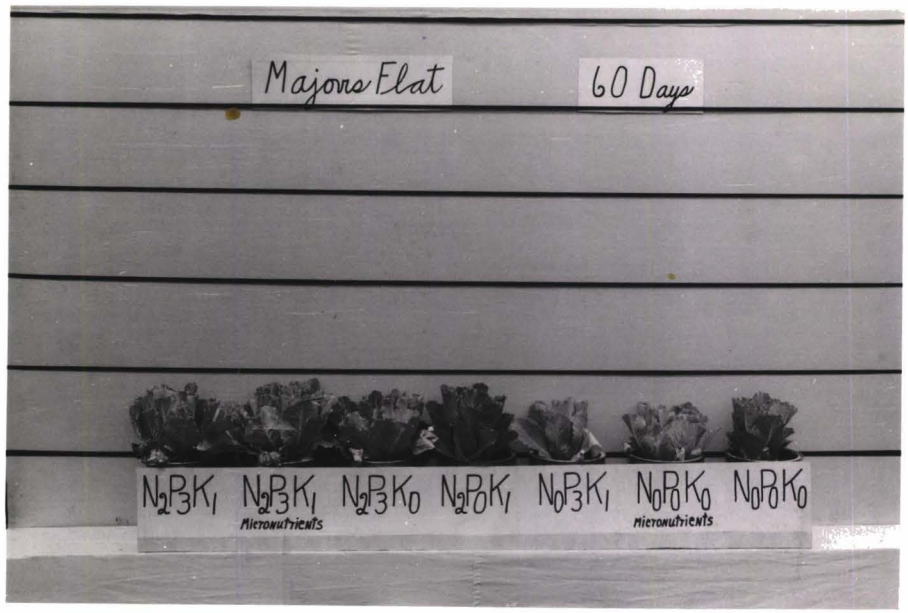


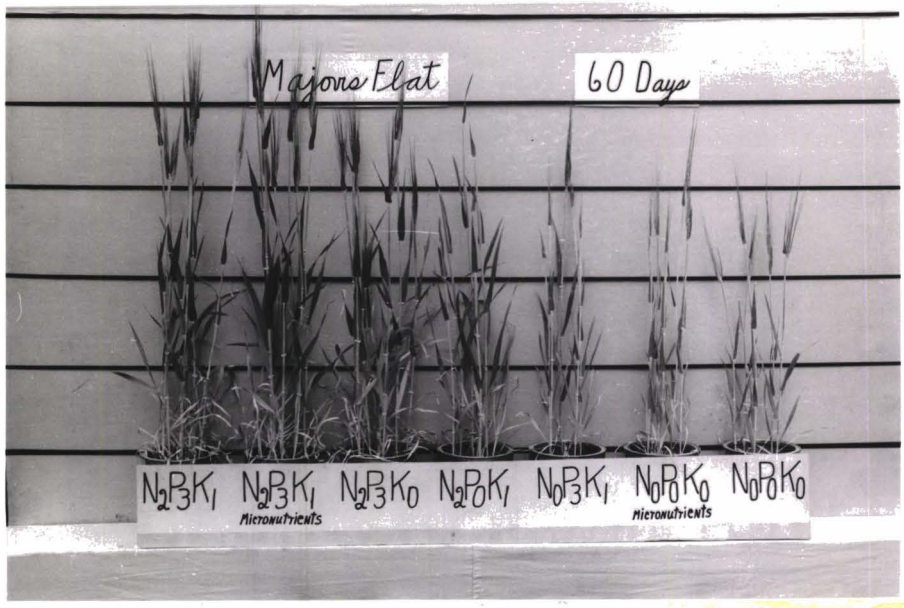
Figures 37 and 38.—Growth of Romaine lettuce and Bonneville barley in 60 days on soil from Philadelphia Flat which had received various macronutrients and micronutrients (B57-60 and B57-59).





Figures 39 and 40 .--Growth of Romaine lettuce and Bonneville barley in 60 days on soil from above the Alpine cabin in Ephraim Canyon which had received various macronutrients and micronutrients (B57-66 and B57-65).





Figures 41 and 42 .--Growth of Romaine lettuce and Bonneville barley in 60 days on soil from Majors Flat which had received various macronutrients and micronutrients (B57-70 and B57-69).

III-D-1. Uniform study for seeding depleted sites on western range

Plans to establish a uniform study were first made at the Range Society Meetings held at Great Falls in January 1957. This study is to be conducted at six locations, as follows: Bozeman, Montana; Ephraim, Utah; La Grande, Oregon; Logan, Utah; Pullman, Washington; and Reno, Nevada. A general plan of study was made from the composite suggestions by Dr. Keller and the field men located at the locations shown above. A. C. Hull has acted as coordinator, and has assembled this material into study plan form.

The first rough draft of the study was prepared on April 22, 1957. Several revisions have been made to incorporate changes and new material, but the major study treatments were decided on in time for establishment of proposed treatments in the fall of 1957. Nine seedbed treatments were to be applied on the contour and five fertilizer treatments applied up and down the slope at right angles to seedbed treatments. This is a variant of the split plot design. The following treatments are to be applied:

Seedbed treatment

1. Plow fall 1957 - fallow - seed fall 1958
2. Nurse crop fall of 1957 - seed fall 1958
3. Plow fall 1957 - seed spring 1958
4. Spray spring 1958 - seed fall 1958
5. Plow, seed, and sawdust mulch plus nitrogen, fall 1957
6. Plow, contour furrows, seed fall 1957
7. Plow fall 1957 - transplants fall 1957 or spring 1958
8. Plow and seed fall 1957

9. No seedbed or planting

Fertilizer treatments

1. Nitrogen
2. Phosphorus
3. Nitrogen and phosphorus
4. Nitrogen, phosphorus, potash, and minor elements
5. No fertilizer

These treatments are to be uniformly carried out at all locations. Five species will be used at all locations. Smooth brome and slender wheatgrass will be used at all locations except where they are not adapted. In addition plant data, soil data, climatological data and photographs should be taken uniformly at all locations.

Plantings were made according to plan at two locations in Ephraim Canyon on October 10 and October 18, 1957. These plantings were made on Forest Service land within an enclosure constructed by the Forest Service for this purpose. These enclosures are large enough to provide ample space for additional planting in subsequent years. This study incorporates the methods of planting and fertilization treatments established in Ephraim Canyon in the fall of 1955 by W. J. McGinnies and the similar study established in the fall of 1956 (See Section III-C-3).